AD-A182 282 MICROCOMPUTER PRODUCTIVITY STUDY FOR THE NAVAL TRAINING SYSTEMS CENTER(U) NAVAL TRAINING SYSTEMS CENTER ORLANDO FL W A KNIGHT ET AL DEC 86 NTSC-TR-86-028 1/1

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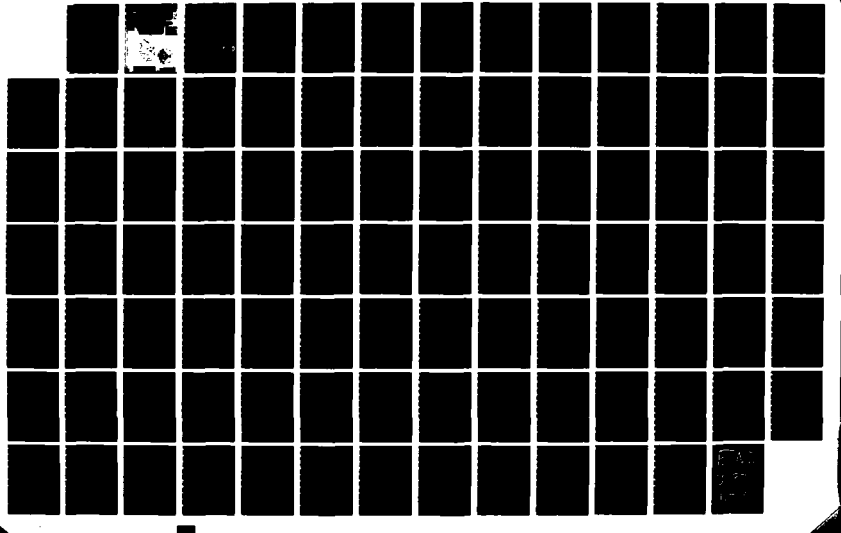

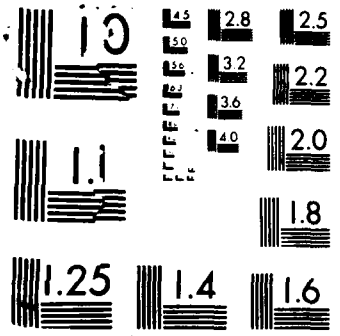
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NAVAL TRAINING SYSTEMS CENTER
ORLANDO, FLORIDA

TECHNICAL REPORT 86-028

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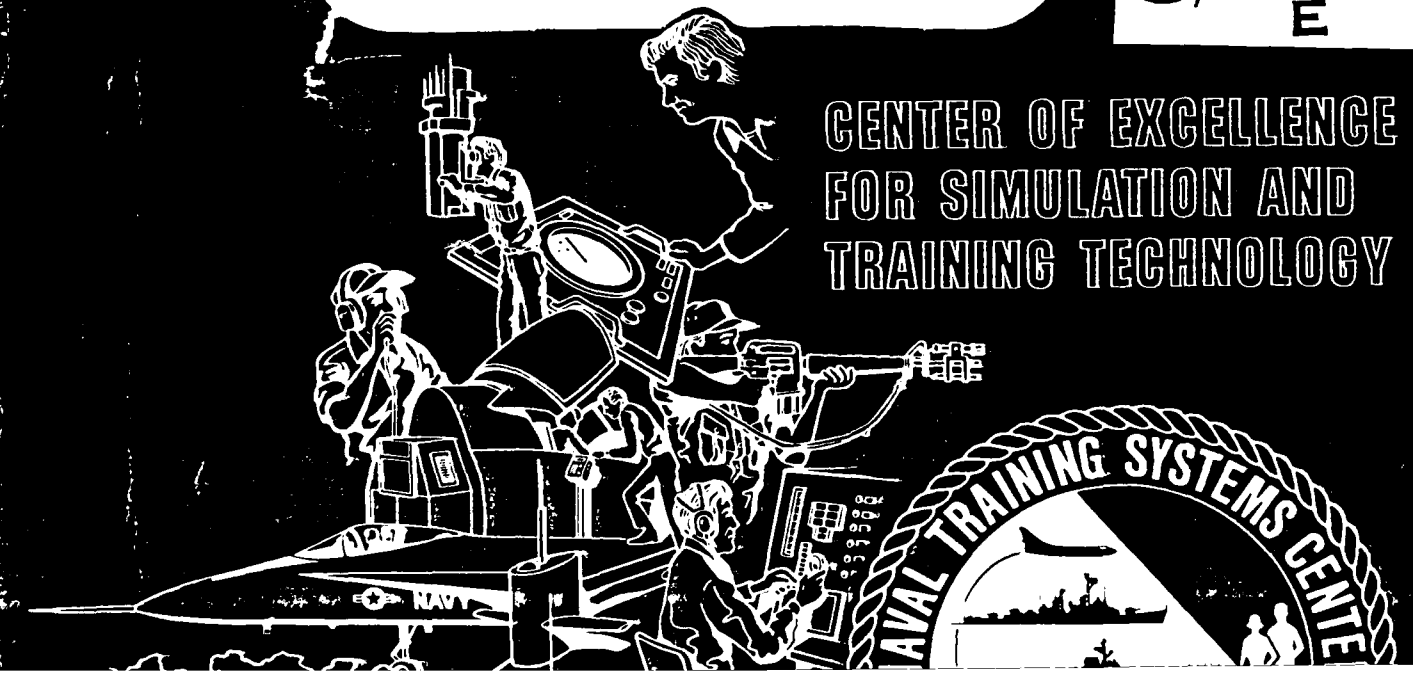

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MICROCOMPUTER PRODUCTIVITY STUDY FOR THE NAVAL TRAINING SYSTEMS CENTER

DECEMBER 1986

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Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

AD-A182282

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report 86-028	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Training Systems Center (Code 123) 6b. OFFICE SYMBOL (If applicable) NAVTRASYSCEN	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Naval Training Systems Center Department of the Navy Orlando, FL 32813-7100	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11. TITLE (Include Security Classification)

MICROCOMPUTER PRODUCTIVITY STUDY FOR THE NAVAL TRAINING SYSTEMS CENTER

12. PERSONAL AUTHOR(S)
Wayne A. Knight, Bethia J. Best, Scott W. Dunlap

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM _____ TO _____	December 1986	93

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP
05	01	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Office Automation, Productivity, Microcomputer, Word Processing, Database, Spreadsheets.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The NAVTRASYSCEN began the automation of its office activities by putting in place a significant number of microcomputers (MC's), primarily Zenith Z-120s, and a variety of software programs and peripherals.

This study had two broad objectives: (1) Identify and survey the location and utilization of MC systems at the Center; and (2) Evaluate the changes in employee productivity and MC satisfaction resulting from the use of the MC systems.

Supervisor and individual survey questionnaires were developed and administered to all NAVTRASYSCEN employees. The questionnaires asked employees for the location and utilization of the MC systems, the estimated effects of using the MC's on their own productivity, and their satisfaction with these systems. A cost-benefit analysis was performed.

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT XX UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Wayne A. Knight	22b. TELEPHONE (Include Area Code) (305) 646-4550 / 22c. OFFICE SYMBOL NAVTRASYSCEN Code 123

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. ABSTRACT (Continued)

STUDY FINDINGS

(1) An overwhelming majority of NAVTRASYSCEN users perceived that their productivity had substantially increased since they began using a MC. Further, 97 percent of the fielded MC's were being used. (2) The cost analysis confirmed that the fielded MC's are highly cost-effective. Each dollar the Center has spent or will spend on the acquisition, installation, training, and maintenance of MC's over the life of the program will yield improvements in output valued at approximately $3.70 in present value terms. (3) The major software applications were word processing, electronic spreadsheets, and data management. (4) Nineteen percent of employees were potential new MC users; 10 percent of employees had jobs that did not require a MC. (5) Nonsupervisors had greater productivity gains than supervisors. (6) Clericals increased their productivity more than workers in other job categories. The major software application for this group of users was word processing. (7) Users with a private MC had greater productivity gains than users who shared a MC. However, the greatest productivity gains in this category were made by people with a private MC at their own work station who also had access to alternate equipment for special functions. (8) Highly satisfied users had greater productivity gains than moderately satisfied users. Recommendations for improving productivity are provided.

ACKNOWLEDGMENTS

Appreciation is expressed to the following persons for their contributions to this study:

- Thomas O. Peeples for his assistance in performing statistical analyses.
- Malinda M. Pepper for providing personnel data.
- Edward O. Moore, Jr. and his staff for their participation in the pilot study.

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EXECUTIVE SUMMARY

PROBLEM

The Naval Training Systems Center (NAVTRASYSCEN) began the automation of its office activities by putting in place a significant number of microcomputers (MC's), primarily Zenith Z-120s, and a variety of software programs and peripherals. An evaluation of the Center's current MC applications was needed to support, if appropriate, further requests for office automation.

OBJECTIVES

This study had two broad objectives: (1) Identify and survey the location and utilization of MC systems at the Center; and (2) Evaluate the changes in employee productivity and MC satisfaction resulting from the use of the MC systems.

APPROACH

Supervisor and individual survey questionnaires were administered to all NAVTRASYSCEN employees. The questionnaires asked employees for the location and utilization of the MC systems, the estimated effects of using the MC's on their own productivity, and their satisfaction with these systems. A cost-benefit analysis was performed.

RESULTS

This study showed that 97 percent of the MC's at the Center were being used and Zeniths represented 87 percent of all MC's. The primary software applications and the percentages of users who reported using each application were: word processing, 88 percent; electronic spreadsheets, 45 percent; and data management, 47 percent.

A majority of the 935 MC users reported gains on all of the productivity measures as adjusted by time spent on a MC. Percentages of users who reported productivity gains ranged from 68 percent for volume of output to 79 percent for completing tasks more quickly. Average productivity gains ranged from a 16.4 percent reduction in errors to a 20 percent better quality of output. Seventy-four percent of users had a 17.6 percent gain in overall productivity. Further, 66 percent of 870 users reported that using a MC enabled them to add new tasks and 48 percent of 829 respondents eliminated unneeded tasks. As time spent on a MC increased, the percent of users in each time category who added or eliminated tasks increased.

There was a relationship between the productivity measures and the following employee categories: supervisory status, U.S. Department of Labor job categories, user MC satisfaction, access to MC, private or shared MC, and task loads. Employees in all categories reported that using a MC enabled them to complete tasks

more quickly, make fewer errors, increase quality and volume of output, increase overall productivity, add new tasks, and eliminate unneeded tasks. However, significantly greater productivity gains were made by users with a private MC, non-supervisors over supervisors, clericals over other job categories, highly satisfied over less satisfied users, and users with a private MC at their own work station who also had access to alternate equipment for special functions.

The extent of MC sharing at the Center was reported as follows: 191 users shared with one other user, 121 with two users, 75 with three users, 50 with four users, 26 with five users and 44 with six or more coworkers. Further, 79 percent of 414 sharers said they would use a MC more if they had their own.

The cost-benefit analysis showed that the total discounted values of productivity improvements and costs were $17.4 million and $4.7 million for a 6-year period. The difference of $12.7 million divided by the total discounted value of output of $227.1 million yielded a net productivity gain of 5.6 percent.

CONCLUSIONS

1. An overwhelming majority of the NAVTRASYSCEN users perceived that their productivity had substantially increased since they began using a MC. Further, 97 percent of the fielded MC's were being utilized.

2. The cost analysis confirmed that fielded MC's are highly cost-effective. Each dollar the Center has spent or will spend on the acquisition, installation, training, and maintenance of MC's over the life of the program will yield improvements in output valued at approximately $3.70 in present value terms.

3. The major software applications being used were word processing, electronic spreadsheets, and data management.

4. Nineteen percent of employees were potential new MC users; 10 percent of employees had jobs that did not require a MC.

5. Nonsupervisors had greater productivity gains than supervisors.

6. Clericals increased their productivity more than workers in other job categories. The major software application for this group of users was word processing.

7. Users with a private MC had greater productivity gains than users who shared a MC. However, the greatest productivity gains were made by people with a private MC at their own work station who also had access to alternate equipment for special functions.

8. Highly satisfied users had greater productivity gains than moderately satisfied users.

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INTRODUCTION

PROBLEM

The purpose of this study was to (1) identify and survey the location and utilization of the microcomputers (MC's) and (2) conduct an evaluation of changes in employee productivity and satisfaction resulting from their use.

OBJECTIVES

The specific objectives of this study were:

1. Perform a literature review of research dealing with the impact on productivity resulting from the use of MC's in the office workplace.

2. Identify and survey the location and utilization of MC systems which have been allocated among the NAVTRASYSCEN departments.

3. Develop a method for determining productivity changes resulting from the application of MC's to support the work of the NAVTRASYSCEN staff.

4. Using the above methodology, estimate the impact on productivity and MC satisfaction resulting from the use of MC's at the NAVTRASYSCEN.

5. Make recommendations which will improve productivity.

BACKGROUND

The NAVTRASYSCEN began the automation of its office activities by putting in place a significant number of microcomputers (MC's), primarily Zenith Z-120s, and a variety of software programs and peripherals. The MC's were placed at numerous work stations. They are used for a wide range of functions such as, word processing, electronic spreadsheets, data base management, and software development.

The Center periodically submits requests for productivity improvement funds to further enhance operational efficiency. An evaluation of the Center's current MC applications is needed to support, if appropriate, further requests for office automation.

ORGANIZATION OF THE REPORT

In addition to the Introduction, this report has the following sections: Executive Summary, Literature Review, Method, Results, Summary, Conclusions, Recommendations, and Tables and Figures.

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LITERATURE REVIEW

OVERVIEW

A literature search was performed of Government and civilian documents and publications that reported productivity data on the effects of using MC's in the office. The literature suggests that microcomputers (MC's) and available software packages have had a significant impact on employee productivity in the office (Kneale, 1985). For purposes of this study, productivity improvement is defined as an improvement in the output/input ratio. Therefore, improvement in productivity can be realized as improvement in the quantity or quality of output; reduction in inputs; or a combination of both. Advances in technology have increased the capability of MC's and reduced their price. Many companies, realizing the value of MC's, have bought systems in massive numbers. A Dun and Bradstreet survey conducted in 1985 showed that 71 percent of companies with more than 100 employees have and use personal computers. This is up by 48 percent in just 2 years (Winslow, 1985).

Research performed by Amy Wohl, president of Wohl Associates, an office automation consulting firm, has shown that up to 34 percent of the office desks had computers in highly automated companies. The companies studied indicated that 100 percent of those desks will have computers by the year 2000. According to Future Computing Inc., office automation is most prevalent in the areas of banking and finance, 46 percent; insurance, 37 percent; real estate, 34 percent; and manufacturing, 33 percent (Hinman, 1986).

Honeywell Technalysis sponsored a nationwide study, conducted by Public Attitudes of New York, in which corporate finance officials were asked how they would spend $10,000 to increase their productivity. Eighty-one percent indicated they would purchase a computer, software, or a word processor. Only 6 percent indicated they would hire additional personnel. Eighty-four percent had word processing equipment available for their own use, 80 percent had computers, and 67 percent had personal computers. Ninety-five percent of the professional finance workers that have office automation equipment indicated they use the equipment ("Corporate finance personnel", 1985).

The proliferation of MC's, software, and peripherals, allows companies to design a system to meet their specific needs. Despite the capabilities and adaptability of such equipment, some organizations find that this new technology will not improve their productivity. In a statement to the Wall Street Journal, Elizabeth H. Menten of Gartner Group, a Stamford, CT consulting firm, indicated that 60 percent of her clients want more ways to document personal computer productivity (Kneale, 1985).

APPLICATIONS

In 1985, the major personal computer applications were: accounting, 73 percent; financial analysis spreadsheets, 65 percent; word processing, 57 percent; data base management, 38 percent; inventory control, 32 percent; purchasing, 23 percent; and credit analysis of customers, 14 percent (Kneale, 1985). The three software packages used most often in the office environment are word processing, electronic spreadsheets, and data base management. Although computer applications are widespread, customers utilize only a fraction of the computer's potential. In a statement to the Wall Street Journal, Vice President of the Intel Corp., Andrew S. Grove said, "Customers get great boosts in productivity from personal computers, but still exploit only 5 percent of the machines' full capability" (Kneale, 1985). This is primarily due to the fact that software development companies do not know user needs. Although many software programs are now available, there remains a tremendous gap in the development of software.

Word Processing

The word processing application is used primarily by secretaries. However, it is also used by management level personnel and highly skilled professionals. Most productivity evaluations address MC benefits in terms of improved quality of products, improved worker satisfaction, reduced turnaround time, increased availability of information, and reduced file storage capacity. The General Services Administration's (GSA) evaluation of word processing productivity is one such case. They cited the elimination of a number of files, a reduction in the number of missed due dates, the elimination of recurring typing of certain correspondence containing "boilerplate" paragraphs, quicker modification of documents, elimination of paperwork through electronic filing, and considerable time savings and elimination of paperwork (General Services Administration End User Computer Support Staff, 1983).

Electronic Spreadsheets

Electronic spreadsheets have greatly reduced the time and labor required to prepare and update documents requiring the input, manipulation, calculation, and presentation of data. Spreadsheets are used primarily in the financial, engineering, and management disciplines. A survey of 100 corporate executives from the Fortune 500 companies was conducted by Trinet Inc. of Parsippany, NJ, to determine how they used their computers ("Top executives increase", 1985). The executives used spreadsheets for financial analysis, current budget planning, current market

intelligence, long-range planning, public affairs, and personnel management. Approximately 77 percent of the respondents have used computers for less than 2 years. The executives indicated an increase from 8 percent to 35 percent in their computer proficiency in the last 2 years.

The Office of Management Support, Office of Oversight reported that through the use of spreadsheets, documents can be produced in 5 to 8 minutes where they used to take 2 hours. In addition to taking 93 percent less time to produce, reports are more accurate and lend themselves easily to change. Overall, the use of spreadsheets increased accuracy, saved about 2 staff months a year, and absorbed a 25 percent increase in workload in FY 83, with no increase in staff. Current staff can now perform more in-depth analyses, financial projections, and trend analyses. The MC's have paid for themselves 10 times over by saving about $60,000 which would have been required to pay for two additional budget analysts to perform the added work (General Services Administration End User Computer Staff, 1983).

Data Base Management

Data bases enhance the ability to enter, retrieve and manipulate data. Using a data base, which was developed internally, GSA's Office of Stockpile Transactions was able to: increase accuracy and productivity; develop a contract status report which was previously prepared informally; and monitor contracts of personnel not in the office. Also, they responded more quickly to requests for information, in spite of reduced staffing levels. The Office of Real Property cited the following benefits: increased accuracy, reporting frequency increased to monthly and on time, and 134 percent of FY 82 sales volume processed in FY 83 in less time than original volume. Overall, the GSA reported that the use of data base management software eliminated manual handling, sorting, and calculating information. It tremendously increased quality and accuracy of work scheduling, increased service, provided more accurate records, and eliminated paperwork (General Services Administration End User Computer Staff, 1983).

LOCAL AREA NETWORKS

MC's can communicate with other MC's or with large "mainframe" computers through the use of local area networks (LAN's). Communicating with a mainframe allows a MC user to access the mainframe's large memory for information which cannot be stored in a MC. Travelers Insurance Co. reports that of the 8500 independent agents who sell Travelers insurance, 1500 are linked to the company's mainframe. The linking reduced cost and saved time. It increased the accuracy of policy preparation because the assistance of a field office is no longer required. As a result, Travelers consolidated their field offices from 90 to 15 (Winslow, 1985). The GSA utilizes a LAN called Nestar to link

84 IBM personal computers. Their productivity increased while reducing cost in 79 percent of the categories which were evaluated. GSA uses this system primarily for word processing, electronic mail, data management, project management, calendaring, and graphics. An impact study showed that in 39 of 47 job categories, the volume of work produced increased. The study also showed that in 14 out of 19 cases, the time required to accomplish certain jobs was significantly reduced. In addition, managers found they spent less time on the telephone and at meetings because of electronic mail and teleconferencing capabilities (Saxton & Edwards, 1985).

Installation of LAN's is not always easily accomplished. The use of the LAN, once installed, does increase productivity, but the decision to install a LAN can be quite complicated. The development of LAN's is still in its infancy. Companies, such as American Express, are concerned that by the time they can link 16 data centers, 90 mainframes, 400 minicomputers, 22,000 terminals, and 3,000 personal computers, technological advances would make their system obsolete. There is also a political issue concerning the fact that some departments do not want to share information with other departments. A telecommunications manager at the General Electric dishwasher plant in Louisville, KY, Bobby N. Lewis, reflects the same concern. He states, "Down here we feel the {local area network} technology is still a maturing one. And there are a lot of ways to skin that network cat" (Kneale, 1986).

OFFICE AUTOMATION

Many of the studies which have been conducted do not identify specific applications such as word processing or spreadsheets. Instead, they address the automation of the office as a whole. Such is the case with a study called Laboratory Office Network Experiment (LONEX) conducted for the Rome Air Development Center. A centrally located computer with a local area network and terminals was used instead of stand-alone MC's. However, results of the study appear to be consistent with the use of MC's. The study noted that professionals who prepare their own memos and reports and secretaries indicated that the office automation equipment allowed them to make changes to documents easily and quickly. This allowed them to pay more attention to format and the correction of typographical and grammatical errors. Fifty-three percent of the participants reported an increase in the quality of products; 70 percent said that the equipment improved the appearance of products. Additional benefits included reduced turnaround time, increased availability of information, and reduced file storage capacity (Booz, Allen Hamilton, 1984).

General Telephone and Electronic (GTE) Communication Systems automated its office with an office system computer, 16 on-line display terminals, and six printers. The office automation

equipment allowed secretaries to save significant amounts of time by keying and correcting letters, memos, forms, and reports compared to using conventional electric typewriters. Mr. R. Zeien, a GTE manager, said, "When you free secretaries from typing and retyping most documents, you allow them to become more effective administrative aids" (Automation and Productivity, 1984). Additionally, many engineering and supervisory personnel could fine-tune their own written communications without overloading their secretaries with typing. As a result, written communications were produced more quickly and were more clear and concise.

In contrast, the office automation project sponsored by the Naval Supply Systems Command (NAVSUP) had some different results. The project involved the installation of office automation equipment in the Contracting Services Branch (Code 0262) at the U.S. Navy Ships Parts Control Center (NSPCC), Mechanicsburg, PA. Evaluation of the project began by establishing baseline productivity levels in the areas of labor efficiency, output quality, and timeliness of completed documents. Productivity of the code as a whole, rather than individual productivity, was evaluated. After installation of the office automation equipment in June of 1981, two separate measurements of office productivity were conducted. The first interim and second interim productivity measures covered the September 1981--February 1982 and October 1982--May 1983 time frames, respectively. Each measurement revealed that the branches' average productivity levels declined from the baseline levels with the use of the office automation equipment. The first interim measurement showed an average labor efficiency of 81 percent of baseline; quality was about the same as before automation; and timeliness improved due to reduced workload. The second interim measurement showed that labor efficiency averaged 72.5 percent of baseline. The error rate was 16.3 percent of baseline for contract preparation and 10 percent of baseline for purchase document preparation. Timeliness was poor for November 1982--February 1983 but improved from March 1983--June 1983. Factors which influenced the decline in productivity of the LONEX study included: a below normal work load; training time for using the new technology may have been underestimated; the printing device was inappropriate for the application; and there was high personnel turnover (Daly, 1983).

ATTITUDES

Attitudes of employees can be affected by office automation. During the GSA pilot project, workers' morale increased due to their appreciation of management's recognition of a need for state-of-the-art equipment (Saxton Edwards, 1984).

When participants of the Honeywell Technalysis survey were asked if office automation equipment helped them in making better and more informed decisions, 95 percent said it did, and 86

percent said it benefited them personally. The personal computer was rated by 97 percent of the finance professionals as being very useful while other office automation equipment or technologies such as teleconferencing and electronic mail were rated less useful. When asked how easy the computers were to learn, 79 percent of the finance personnel said they were very or somewhat easy to learn. Eugene Manno, Vice President of Honeywell's small computer and office systems group, said of the survey respondents, "They said they can do more work of higher quality in a shorter amount of time than they could without these tools" ("Corporate finance", 1985).

Seventy percent of the personnel who participated in the LONEX study indicated that their working group was more efficient as a result of automation and that they were interested in using an enhanced operational system. Further, professionals indicated that with the automation equipment they felt they had more control and freedom which improved the general nature of their jobs. The professionals liked the fact that they could be more spontaneous; produce legible drafts on the keyboard instead of in longhand; and fine tune documents without overloading the secretary with typing. Secretaries expressed the feeling that pressure to produce a quality product was reduced because last minute changes to documents could be made easily. They reported they would have less job satisfaction if they had to work in an office without office automation equipment (Booz, Allen, Hamilton, 1984).

Concerning the removal of MC's from their offices, the GSA said, "To eliminate the MC at this point would be equivalent to eliminating the automobile in favor of a covered wagon, or perhaps an even better analogy would be eliminating a guided missile in favor of a bow and arrow." (General Services Administration End User Computer Support Staff, 1983).

COST SAVINGS

The cost of placing MC's in the office can be more than offset by increases in work output. The results of the General Services Administration's (GSA) pilot project were so good that the GSA strongly suggested that Government office managers implement office automation programs. Significant dollars were saved without a reduction in personnel. The central office spent $102,000 on their hardware and software; they saved approximately $173,000 in one year because of the additional projects which were completed. The regional offices spent approximately $200,000 on hardware and software. Employees had an average of 4 months experience with MC's. Seven of the eleven regions realized a combined annual savings of $255,000. The GSA achieved a payback time of less than one year on its purchase of the MC's (General Services Administration End User Computer Support Staff, 1983).

In 1970, Travelers had 30,000 employees, two-thirds of which were clerical and one-third professional. By 1990, Mr Brophy, Senior Vice President for data processing, estimates that these figures will be reversed. The MC has enabled personnel at Travelers' Constitution State Management Co. a subsidiary, to increase their analysis of premiums from $7 million to $34 million in one year without hiring more people. They found that agents could use the MC to prepare insurance policies faster and more accurately than with previous methods. Additionally, they were able to assume the underwriting function formerly performed in field offices. This significantly reduced the time and labor required for the preparation of policies. Travelers now have approximately 9000 MC's including about 4500 owned by independent agents (Winslow, 1985).

SUMMARY OF THE LITERATURE

A review of the literature obtained from both Government and civilian sources indicates that, in most cases, the use of MC's, software packages, ancillary equipment, and other office automation equipments has a positive effect on the productivity of office workers. A reduction in the cost of MC's, an increase in software applications, and proof that MC's increase productivity has prompted businesses to purchase large numbers of MC's. Productivity improvements were cited in the areas of increased quality of work, increased quantity of work, reduction in the number of errors, increased volume of work, and savings of significant amounts of money. The major areas of MC use were identified as word processing, data base management, and electronic spreadsheets.

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METHOD

POPULATION

All employees of the NAVTRASYSCEN, Orlando, Florida were included in the microcomputer (MC) survey. Two questionnaires were developed to collect data on the location and utilization of all MC systems at NAVTRASYSCEN, and on employee perceptions of productivity and satisfaction with the MC systems.

QUESTIONNAIRES

Supervisor Questionnaire

The first questionnaire asked supervisors to provide organizational level summary information for their unit (appendix A). In the case of department and division level offices, these summary data typically represented the unit head and one or two support personnel. Branch heads reported for their entire code. Care was taken to avoid duplication of data. The supervisory data were combined to yield statistics by department (e.g., Code 1, Code 2, ... Code 7), and by organizational level (e.g., department, division, and branch).

Individual Questionnaire

The second questionnaire asked individuals, including supervisors, to provide personal information about their MC use, productivity, and satisfaction (appendix A). These data were combined to yield statistics by supervisory status, MC satisfaction, MC access, MC sharing, and by U.S. Department of Labor job categories. Job category data were obtained by classifying the NAVTRASYSCEN employees according to their job series into one of the following nine mutually exclusive Department of Labor job categories: (1) engineer/scientist technicians; (2) scientists/engineers; (3) other professionals; (4) management/administration; (5) other technicians; (6) clerical; (7) other GS/GM; (8) crafts/mechanical; and (9) operatives/service.

PROCEDURES

Individual questionnaires were sent to 1,393 employees including 170 supervisors. The supervisors also were sent a supervisory questionnaire. A cutoff date for the return of questionnaires was established. Data from forms received after the cutoff date were excluded.

Completed questionnaires were processed in strictest confidence. Each questionnaire was given an identification number and the name was blacked out. Forms that were returned without a name or code were discarded because they could not be

identified. Quantitative data that fell outside normal parameters, were verified or corrected based on follow-up telephone calls with personnel who provided the information.

DEPENDENT MEASURES

There were two categories of dependent measures, productivity and task loads.

Productivity

The effect of MC's on productivity was determined by asking employees to estimate the effect of using a MC on their output in percentage terms of time, errors, quality of output, volume of output, and overall productivity. Subjects put their percentage estimates in one of three productivity columns: percent increase; no effect; or percent decrease.

Task Loads

The effect of MC's on task loads was determined by asking employees to check yes or no on two questions: (1) Have microcomputers allowed you to add new tasks never done before? and (2) Have microcomputers allowed you to eliminate former tasks not now needed?

Microcomputer Use Related to Productivity Measures. Employees checked a time category that most closely represented the number of hours per week (hpw) they used a MC. The categories are 1-3 hpw, 4-10-hpw, 11-20 hpw, 21-30 hpw, and over 30 hpw. Employees were defined as users if they reported using a MC one or more hours per week. Productivity changes were adjusted down by the average hours per week within categories of MC use. This adjustment is based on the assumption that respondents equated their productivity changes to tasks performed on the MC, not to every aspect of their jobs. The formula for the weighting factor is:

Adjusted Percent Productivity =
(Reported Increased Productivity)(Reported hpw Use)/40 hpw

INDEPENDENT MEASURES

The adjusted productivity measures and the task load measures were compared on five independent variables: supervisors versus nonsupervisors; U.S. Department of Labor job categories; user MC satisfaction; MC own workstation or access away; and private or shared MC.

STATISTICS

The statistics for this report were aggregated from two sources, supervisor questionnaires (n=161) and individual questionnaires that also included supervisors (n=1,322). The data from both sources are identified and presented.

ECONOMIC ANALYSIS METHOD

Method--Valuation of Output

Labor theory generally assumes that the value of an employee's work to the organization is directly associated with the employee's wage rate or salary. Assumptions for the following analysis are: (1) the value of an employee's output per unit of time equals the employee's salary per unit time; (2) the value of total output is the total salary of the sample (n=1261, 56 missing cases); (3) all pay grades are GS Step 6; and (4) the estimated useful life of MC's is 6 years.

The productivity of labor is defined as the output per hour of labor employed. The hours of work are assumed fixed for each employee at 40 hours per week; the number of employees was held constant. Therefore, changes in output can be attributed to changes in productivity. Using the FY 86 value as a base and holding the quantity of labor constant, the value of total output was computed for each year of the life cycle.

Method--Valuation of Productivity

Salary was used as a proxy for the value of each employee's output. Therefore, the estimated value of a change in productivity was derived by multiplying the respondent's salary by the reported change in productivity. Since it was assumed that productivity changes applied only to work done when using a MC, gross estimates of productivity changes were adjusted down by the ratio of weekly MC use to a 40-hour work week. The formula used to compute values of productivity changes is:

(Salary)(Percentage change)((Hours use)/(40 hpw))

For example, the value of the change in productivity for an employee who earns $30,000 a year, reported a 40 percent increase in productivity, and reported using a MC 15 hours per week is computed as follows:

($30,000)(.40)(15/40) = $4,500

Application of the Learning Curve. Learning curve theory suggests that when a new task or process is undertaken a person learns as the task or process is repeated. The more the task or process is repeated, the more efficient the person becomes.

Increases in efficiency translate into fewer inputs such as labor effort, equipment, and supplies for a given level of output, reducing production costs.

Application of learning curve theory was considered appropriate because acquisition of MC's began during fiscal year 1984 and the surveys were completed in mid-1986. Productivity changes reported in 1986 follow 2 years of experience using MC's. During the period of adjustment to using a MC, it is unlikely that absolute gains in productivity would be equal to or as large as absolute gains occurring after 2 years of use. However, the rate at which productivity changes were realized would decrease over time as MC users became more familiar with potential applications of both hardware and software.

The learning curve is usually seen as an inverse variation curve--as the units of output increase the unit cost decreases. However, productivity gains for this analysis were examined from a value of output perspective--a direct variation curve. The general formula used to represent a learning curve in this application is $Y = (A)(B^X)$ where:

Y = Value of gain (dependent variable)
B = Time in years (independent variable)
A = First year gain (constant)
X = Learning curve exponent (constant)

Assuming an 80.5 percent learning curve (X = .312), constant labor input, and a 6 year life cycle for MC's, the following derivation illustrates how productivity gains were estimated for years other than FY 86.

FY 86 was the third year of a 6-year period for which productivity gains were estimated. The observed Value of Gain (VoG) in FY 86 was $3,209,000. This value was used in the following equation to derive the first year gain (VoG(1)) as illustrated.

$$VoG(n) = (VoG(1))(Year(n)^{.312})$$

Solving for VoG(1), which is the value of the gain in year one and the base value from which all others (VoG(n)) are estimated;

$$VoG(1) = (VoG(n))/(Year(n)^{.312})$$

$$VoG(1) = (\$3,209,000)/(3^{.312}) = \$2,277,760$$

The gain for each of the 6 years can now be computed using the following equation:

$$VoG(n) = (\$2,277,760)(Year(n)^{.312})$$

Method--Life Cycle Cost Analysis

The life cycle cost analysis is based on a 6-year useful life for MC's. Costs associated with the implementation and operation of MC's are categorized as either investment costs or operation and maintenance costs. Buying MC's eliminated the need to continue to buy, lease, and maintain a number of typewriters and word processors. Reductions in costs associated with this equipment are shown as savings. All costs and savings are expressed in constant dollars using FY 86 as the base year and discounted using the factors described below.

Discounted values represent opportunity costs of expenditures relative to mid-1986. Since mid-1986 is the base year, pre-1986 expenditures must be adjusted upward to reflect opportunity costs in terms of the base year. Midpoint discount factors were used, assuming uniform cash flows throughout each 1-year period. The following factors were applied to the estimated values of output and productivity gains:

1984:	1.105
1985:	1.050
1986:	.954
1987:	.867
1988:	.788
1989:	.717

These factors assume a 10 percent discount rate as required by Department of Defense Instruction 7041.3.

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RESULTS

A total of 1324 employees, including 161 supervisors and acting supervisors responded to the microcomputer (MC) survey prior to the cutoff date. Two individual questionnaires were discarded because they could not be identified, leaving a usable sample of thirteen hundred and twenty-two (n=1322). The number of questionnaires varies for some analyses due to missing data. The return rate was 99 percent for supervisor questionnaires and 96 percent for the individual forms. The number and percent of the sample distributed by departments are shown in table 1.*

MICROCOMPUTER EQUIPMENT

Supervisors reported the location and utilization of MC systems in their respective units. Overall, 97 percent of the MC's at NAVTRASYSCEN were being used and Zeniths represented 87 percent of all MC's. The location of MC's by organizational levels and departments is shown in tables 2 and 3. The distribution of MC's being used and those not in use are shown for organizational levels and departments in tables 4 and 5.

MICROCOMPUTER USERS AND NONUSERS

Independent statistics on the number of MC users and nonusers were derived from both supervisor questionnaires and from individual questionnaires. These data differ because supervisors reported information on the total number of employees (n=1373), while the individual questionnaire data were aggregated self-reports of the sample (n=1322).

The number of self-reported MC users at NAVTRASYSCEN was obtained from individual questionnaires. Overall, 935 employees or 71 percent of the sample were MC users; 134 (10 percent) were nonusers who reported that their job did not require a MC; the remaining 253 (19 percent) nonusers were classified as potential users of MC's.

Supervisors reported that 72 percent of NAVTRASYSCEN employees used a MC for some part of their job. The number and percent of users by organizational level and departments are shown in tables 6 and 7.

Microcomputer Users--Time Spent on Microcomputer

Overall, The largest number of self-reported MC users (22 percent) reported spending 4-10 hpw on a MC.

Departments. The number and percent of the sample from each department distributed by time categories are shown in table 8. For example, in Department 3, 35 percent said they were nonusers,

*Tables and figures are shown on pages 54 to 89 and appendix A.

and 20 percent reported using a MC 11-20 hpw. The time category with the largest number of users was 4-10 hpw (22 percent). The percent of the sample in each time category is shown in figure 1.

The number and percent of MC users in each time category distributed by departments are shown in table 9. For example, in the over 30 hpw category 20 percent of 69 users were in Department 1.

Department of Labor Job Categories. Each employee was classified into a mutually exclusive U. S. Department of Labor job category according to job series. Overall, the scientist engineer category had the most employees, followed in descending order by the management/administration and clerical categories. The labor force composition at NAVTRASYSCEN is distributed by job categories in figure 2.

The number and percent of the sample from each job category distributed by time categories are shown in table 10. For example, in the clerical category, 20 percent of 203 employees said they were nonusers and 27 percent reported 21-30 hpw.

The number and percent of the sample in each time category distributed by job categories are shown in table 11. For example, in the over 30 hours time category, 35 percent of 69 users were scientist engineers and 35 percent were clericals.

Microcomputer Users--Software Applications

Individuals reported the major software applications for which they used a MC. The software application categories were word processing, electronic spreadsheets, data management, and other (e.g. design, analysis, and modeling). The number of MC users who reported software applications was greater than the total number of MC users due to multiple responses. Overall, the primary software applications and the percentages of users who reported using each application were: word processing, 68 percent; electronic spreadsheet, 45 percent; and data management, 47 percent. The percent of users in each software application is shown in figure 3.

Departments. The number and percent of MC users in each department distributed by software applications are shown in table 12 and figure 4. For example, in Department 1, 68 percent used word processing.

The number and percent of MC users who used a given software application distributed by departments are shown in table 13. For example, in the electronic spreadsheet category, 35 percent of users were in Department 4.

Department of Labor Job Categories. The number and percent of MC users in each job category distributed by software applications are shown in table 14. Respondents could report more than one software category. For example, in the management administration job category, 91 percent used word processing.

The number and percent of MC users in each software application category distributed by job categories are shown in table 15. For example, in the data management category, 42 percent were scientists engineers.

Microcomputer Users--Access to Microcomputer

Employees were asked if they had a MC at their own work station (MC own station); and whether they had access to a MC away from their own work station (MC access away). Overall, 49 percent of 637 users with a MC at their own work station also had access away. Fifty-three percent of 533 people who did not have a MC at their own work station, did have access to a MC away from their station and 47 percent had no access to a MC (table 16).

Microcomputer Users--Private or Shared Microcomputer

Overall, 39 percent of 833 respondents had a private MC and 61 percent shared a MC. Sharers were asked if they would use a MC more if they had their own. Seventy-nine percent of 414 sharers said yes.

The extent of computer sharing at NAVTRASYSCEN was determined by asking users how many coworkers shared the MC they used. Table 17 shows these data according to MC access (MC own work station only, MC access away only, and both). For example, 191 users shared a MC with one other person.

The data were clarified by dividing the user sample into two groups: (1) sharers--those who reported sharing a MC; and (2) nonsharers--those who did not share the MC they use (table 18). Looking at 507 sharers, 249 (49 percent) had a MC at their own work station; of these, 118 also had MC access away. There were 258 (51 percent) sharers who only had MC access away. Looking at 326 nonsharers, 324 had a private MC at their work station. Of these, 159 also had MC access away. Two nonsharers had MC access away only.

PRODUCTIVITY

The effect of MC's on productivity was determined by asking employees to estimate the effect of using a MC on their output in percentage terms of time (faster--slower), errors (more--less), quality of output (better--worse), volume of output (more--less), and overall productivity (more--less). Estimated productivity was assumed to apply only to the time that the MC was used.

Therefore, the productivity estimates were adjusted by the reported number of hours per week of MC use. Analyses are presented showing the effect on the adjusted productivity measures of the following independent variables: supervisory status, U.S. Department of Labor job categories, user MC satisfaction, MC access, and private or shared MC. Refer to tables 35 and 36 in appendix A for significance data.

Productivity Reported by Users

The number and percent of self-reported users of MC's with the distribution of their responses for each adjusted productivity measure are shown in table 19. Data are presented for users who reported gains in productivity, no effect on productivity, and reduced productivity. Also presented are missing cases--users who did not report the effect of using MC's on the productivity measures.

Overall, a majority of the 935 users reported gains on all productivity measures as adjusted by time spent on a MC. Percentages of users who reported productivity gains ranged from 66 percent for volume of output to 79 percent for completing tasks more quickly. Productivity gains ranged from a 16.4 percent gain in error reduction to a 20 percent better quality of output. Seventy-four percent of users had a 17.6 percent gain in overall productivity.

Productivity--Supervisory Status

Gains in Productivity. Supervisors and nonsupervisors who reported gains on adjusted productivity measures are compared in table 20. Overall, both supervisors and nonsupervisors reported that using a MC enabled them to complete tasks more quickly, reduce errors, increase quality and volume of output, and increase their overall productivity. However, nonsupervisors had significantly greater gains on each of the productivity measures than supervisors.

No Effect. Six supervisors and 99 nonsupervisors reported no effect of using a MC on their overall productivity. There were not enough cases to determine statistical significance.

Reduced Productivity. One supervisor and 14 nonsupervisors reported reduced overall productivity. The differences were not statistically significant.

Productivity--U.S. Department of Labor Job Categories

Employees were divided into U.S. Department of Labor job categories according to job series and compared on the effect of using MC's on the productivity measures. The seven job categories included in the analyses were technical engineers scientists, scientists engineers, other professionals, management

administration, other technicians, clerical, and other. Excluded from the analyses due to inadequate sample sizes were other GM-GS (n=2 users), operatives service (n=1 user), and craftsmen/ mechanics (n=4 users).

Gains in Productivity. The gains in adjusted productivity measures distributed by U.S. Department of Labor job categories are shown in table 21. Overall, users in all job categories reported greater productivity gains in time, error reduction, quality of output, volume of output, and overall productivity. The significant differences were attributed to the clerical category which had the greatest gains on each of the productivity measures.

No Effect. There were 103 users who reported no effect of using a MC on their overall productivity as distributed by job category. There were not enough cases to determine statistical significance.

Reduced Productivity. Fifteen users reported reduced overall productivity as distributed by job category. The differences were not statistically significant.

Productivity--User Microcomputer Satisfaction

Employees were asked to rate their satisfaction with the MC they used on a scale from 1 to 6, anchoring low and high satisfaction, respectively. The data were combined into three levels of MC satisfaction: low (1-2), moderate (3-4), and high (5-6). The relationships between MC satisfaction and the productivity measures were analyzed.

Gains in Productivity. The gains in productivity measures distributed by low, moderate, and high levels of MC satisfaction are shown in table 22. Overall, users who reported low MC satisfaction and those who reported high MC satisfaction both had significantly greater productivity gains in time, error reduction, quality of output, volume of output, and overall productivity than those who reported moderate MC satisfaction.

No Effect. There were 100 users who reported both no effect of using a MC on their overall productivity and level of MC satisfaction. There were not enough cases to determine statistical significance.

Reduced Productivity. Fifteen users reported reduced overall productivity distributed by MC satisfaction. The differences were not statistically significant.

Productivity--Access to Microcomputer

Employees were asked if they had a MC at their own work station and if they had access to a MC away from their work station. These responses were grouped into three access categories: (1) MC own work station only; (2) access away only; and (3) both--MC own work station and access away.

Gains in Productivity. Gains in productivity measures distributed by the access categories are shown in table 23. Overall, there were significant differences in the relationship between productivity gains and the access category. The greatest productivity gains in time, error reduction, quality of output, volume of output, and overall productivity were reported by users with both a MC at their own work station and access away. Users with only a MC at their own work station had the next largest productivity gains. Users whose only access to a MC was away from their work station had the smallest productivity gains.

No Effect. There were 101 users who reported both no effect of using a MC on their overall productivity and the access category. There were not enough cases to determine statistical significance.

Reduced Productivity. Fourteen users reported reduced overall productivity and the access category. The differences were not statistically significant.

Productivity--Private or Shared Microcomputer

Employees were asked how many coworkers shared the MC they used. These responses were grouped into two share rated tiers: (1) private MC; and (2) shared MC.

Gains in Productivity. The gains in productivity measures distributed by share categories are shown in table 24. Overall, private MC users reported significantly greater productivity gains in time, error reduction, quality of output, volume of output, and overall productivity than those who reported sharing a MC.

No Effect. There were 96 users who reported both no effect of using a MC on their overall productivity and the share category. There were not enough cases to determine statistical significance.

Reduced Productivity. Thirteen users reported reduced overall productivity distributed by the share categories. The differences were not statistically significant.

EFFECT OF THE MICROCOMPUTER ON TASK LOADS

The effect of MC's on task loads was determined by asking employees to check yes or no on two questions. (1) Have microcomputers allowed you to add new tasks never done before? and (2) Have microcomputers allowed you to eliminate former tasks not now needed? Analyses are presented showing the effect on task loads of the following independent variables: supervisory status, U.S. Department of Labor job categories, time categories, user MC satisfaction, MC access, and private or shared MC.

Overall, 66 percent of 870 respondents said a MC enabled them to add new tasks and 48 percent of 829 respondents said they were able to eliminate unneeded tasks (table 25).

Task Loads--Supervisory Status

Users who responded to the task load questions distributed by supervisory status are compared in table 26. Overall, both supervisors and nonsupervisors reported that using a MC enabled them to add new tasks and eliminate unneeded tasks. The differences were not statistically significant.

Task Loads--U.S. Department of Labor Job Categories

Users who responded to the task load questions distributed by job categories are compared in table 27. Overall, users in all job categories reported that using a MC enabled them to add new tasks and eliminate unneeded tasks. The differences were not statistically significant.

Tasks Loads--Microcomputer User Time

Users who responded to the task load questions distributed by time categories are compared in table 28. Overall, there was a significant relationship between task loads and the time categories. As time spent on a MC increased the percent of people in each time category who added or eliminated tasks increased.

Task Loads--User Microcomputer Satisfaction

Users who responded to the tasks load questions distributed by MC satisfaction are compared in table 29. Overall, there was a significant relationship between MC satisfaction and task loads. As levels of MC satisfaction increased, the percent of users who added or eliminated tasks increased. Stated another way, there was a larger percent of users at the high level of MC satisfaction who added or eliminated tasks than at the low level of MC satisfaction.

Task Loads--Access to Microcomputer

Users who responded to the task load questions distributed by the access categories are compared in table 30. Overall, gains in the percent of users who added or eliminated tasks were significantly related to the access categories. The greatest productivity gains were reported by users with both a MC at their own work station and access away. Users with only a MC at their own work station had the next largest gains. Users whose only access to a MC was away from their work station had the smallest gains.

Task Loads--Private or Shared Microcomputer

Users who responded to the task load questions distributed by the share categories are compared in table 31. Overall, a greater percent of users with a private MC added new tasks and eliminated unneeded tasks than users who shared a MC. However, only the new task differences were statistically significant.

ECONOMIC ANALYSIS RESULTS

Results--Valuation of Output

The estimated current values for output and the discounted values of output are shown on lines one and three of table 32. The values of output for FY's 85 and 86 are equal because there was no change in wage rates during that period. The FY 84 value of output was derived by subtracting the four percent raise given between FY's 84 and 85 from the FY 85 value. The FY 87 value includes a three percent raise; FY's 88 and 89 each include a three and one-half percent raise.

Results--Valuation of Productivity

Current and discounted value estimates of productivity gain over the life cycle of the MC's are shown on lines two and four of table 32. The percent productivity gain over the life cycle--excluding cost of the MC's--is computed to be 7.67 percent. This value is obtained by dividing the total discounted value of reported productivity gains by the total discounted value of output. The annual percent productivity gains for each year of the MC's life cycle are shown on line five of table 32 and in figure 5. As employees learn to use MC's they are becoming more productive but the rate of productivity gain tends to decrease as they become more proficient.

Results--Life Cycle Cost Analysis

The life cycle costs and savings associated with the MC's are shown on table 33. Costs and savings are summed horizontally by cost categories and vertically by fiscal year to obtain nondiscounted total costs. Total costs are also shown in

discounted terms to reflect the opportunity cost of expenditures. In this section each cost category is described, including assumptions and computations.

Investment Costs. Investment costs include the hardware and software (H&S) costs of buying the MC's, peripherals, and software. Cost reductions associated with the purchase or lease of typewriters and word processors are also included in the investment cost category.

H&S costs, reflect actual expenditures for FY's 84 and 85. The number of MC's planned for procurement for FY's 86-89 was estimated. The costs for 1988 and 1989 are primarily for replacement MC's and $2,000 is added for miscellaneous purchases of peripherals and software. The average cost per MC is $3,000, including a printer and software. Using this average cost, the H&S costs for FY's 86-89 are computed as follows:

1986:	(350 MC's)($3,000)	=	$1,050,000
1987:	(200 MC's)($3,000)	=	$600,000
1988:	(16 MC's)($3,000)	=	$48,000
		+	2,000
			$50,000
1989:	(16 MC's)($3,000)	=	$48,000
		+	2,000
			$50,000

By the end of 1987 there will be approximately 1,150 MC's fielded at NAVTRASYSCEN, or one for nearly every work station.

The expanded use of MC's has resulted in a reduction in the number of typewriters and word processors (T&WP) purchased. Records indicate that an average of 35 fewer typewriters are being purchased each year. The average cost is $700 per typewriter. Three leased word processors were taken out of service for an annual savings of approximately $7,900. The T&WP annual cost reduction is computed as follows:

Typewriters	(35)($700)	=	$24,500
Word Processors			7,900
			$32,400

Operating and Support Costs. Operating and support (O&S) costs include maintenance, training, supplies, and electricity. The assumptions and calculations for each O&S cost category are described as follows:

Maintenance costs for H&S are relatively low during the first three years of the life cycle because the MC's and peripherals are under manufacturer's warranty. As of FY 87, most of the warranties will have expired, requiring additional resources for maintenance. The annual cost of maintaining 1,150 MC's after 1986 is assumed to be $87 per machine, or a total cost of $100,000 per year.

The assumptions used in estimating the reduction in maintenance costs for T&WP are:

a. Annual maintenance costs equal 10 percent of equipment cost.

b. The typewriters currently in inventory are valued at $500 per machine.

c. The typewriters currently in inventory are utilized 50 percent less than prior to acquisition of the MC's.

Maintenance cost reductions resulting from the purchase of fewer typewriters are computed as follows:

$$(\$32,400)(.10) = \$3,240$$

Maintenance cost reductions resulting from reduced utilization of the 354 typewriters currently in inventory are computed as follows:

$$(354)(\$500)(.10)(.50) = \$8,850$$

The total annual maintenance cost reduction is $12,090.

Training costs for MC users include instruction costs of 27 cents per student hour plus student salaries. There were 16,892 student hours of training in FY's 85-86. The average hourly salary for the students was $10.65 in FY 85 and $12.96 in FY 86. Training costs are computed as follows:

1985: (7326 student hrs.)($10.65 + .27) = $80,000
1986: (9566 student hrs.)($12.96 + .27) = $126,558
1987-89 assumed to be $110,000 per year

Supply costs for H&S and T&WP are estimated using the assumption that $50 per machine is required annually for supplies This includes printer ribbons, printer paper, typing paper, liquid paper, correction ribbons, floppy disks, or other consumable items. Supply costs for H&S are computed as follows:

1984: (330)($50) = $16,500
1985: (680)($50) = $34,000
1986: (950)($50) = $47,500
1987-89: (1150)($50) = $57,500

Supply cost reductions for T&WP are also based on the assumption that typewriters in existing inventory will be utilized 50 percent less. The amount of consumable supplies should decrease because of reduced utilization of typewriters and the elimination of word processors. Supplies will not be required for the 35 typewriters and 3 word processors that were not purchased or leased as a result of fielding the MC's. Supply cost reductions for T&WP are computed as follows:

1984-89: ((38)($50)) + ((354)($50)(.50)) = $10,750

Electricity is another resource consumed by the MC's, typewriters, and word processors which must be considered. Electricity costs are based on an operating cost of one cent per hour for H&S and T&WP. The assumptions used in estimating electricity costs are:

a. MC's systems are turned on 1,373 hours per year, or approximately two-thirds of one man-year (2,080 hours).

b. Typewriters and word processors would have been operated 1,373 hours in the absence of MC's.

c. Existing typewriters are utilized 50 percent less (684 hours).

d. The operating cost of one cent per hour is based on electricity cost of eight cents per kilowatt-hour.

Electricity costs for H&S are computed as follows:

1984: (330)(1,373)($.01) = $4,531
1985: (680)(1,373)($.01) = $9,336
1986: (950)(1,373)($.01) = $13,044
1987-89: (1150)(1,373)($.01) = $15,790

Electricity cost reductions for T&WP are computed as follows:

1984-89: [(38)(1,373)($.01)] + [(354)(684)($.01)] = $2,943

Results--Cost Versus Benefits of Microcomputers

The value of benefits from the fielded MC's has been derived from (1) estimates of reported changes in productivity and (2) the assumption that productivity changes are equated to salaries or wage rates paid to employees who experienced changes. An

estimate of the value of these benefits for each year of a six year life cycle is shown in table 34. They are summed to obtain total benefits which are presented in discounted terms.

Summary--Cost versus Benefits of Microcomputers. The total discounted value of benefits was computed at $17.4 million. The total discounted cost of acquisition, installation, training, and maintenance for the MC's over a six year life cycle was computed at $4.7 million. The difference of $12.7 million is the net discounted total value of benefits--the value of output that could not have been produced without the use of MC's--using the same amount of labor. This value, divided by the total discounted value of output of $227.1 million, yields an overall net productivity gain of 5.6 percent. Each dollar the Center has spent, or will spend on the acquisition, installation, training, and maintenance of MC's over the life of the program, will yield improvements in output valued at approximately $3.70 in present value terms.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

This study surveyed 1322 employees of NAVTRASYSCEN to determine the location and utilization of all microcomputer (MC) systems at the Center, and employee perceptions of productivity and satisfaction with these systems. A cost-benefit analysis was performed.

Microcomputers--Hardware and Software

Supervisors reported that 97 percent of the MC's at NAVTRASYSCEN were being used and that Zeniths represented 87 percent of all MC's. The primary software applications and the percentages of users who reported using each application were: word processing, 88 percent; electronic spreadsheet, 45 percent; and data management, 47 percent.

Overall Results--Productivity and Task Loads

Seventy-one percent of 1322 employees reported that they used a MC; 10 percent said their job did not require a MC; the remaining 19 percent were nonusers who can be targeted as potential MC users. The largest group of self reported MC users (22 percent) reported spending 4-10 hours per week on a MC.

A majority of the 935 users reported gains on all productivity measures as adjusted by time spent on a MC. Percentages of users who reported productivity gains ranged from 68 percent for volume of output to 79 percent for completing tasks more quickly. Productivity gains ranged from a 16.4 percent reduction in errors to a 20 percent better quality of output. Seventy-four percent of users had a 17.6 percent gain in overall productivity.

Sixty-six percent of 870 users reported that using a MC enabled them to add new tasks and 48 percent of 829 respondents were able to eliminate unneeded tasks. There was a significant relationship between task loads and intensity of MC use. As time spent on a MC increased, the percent of users in each time category who were able to add new tasks or eliminate unneeded tasks increased.

Supervisory Status--Productivity and Task Loads

MC's are used by 65 percent of supervisors and 71 percent of nonsupervisors. Both supervisors and nonsupervisors reported that using a MC enabled them to complete tasks more quickly, make fewer errors, increase quality and volume of output, and increase their overall productivity. However, nonsupervisors had significantly greater gains on each of these productivity measures than supervisors. Also, both supervisors and nonsupervisors were able to add new tasks and eliminate unneeded tasks.

U.S. Dept. of Labor Job Categories--Productivity and Task Loads

The three job categories with the largest number of employees were scientists/engineers, management/administration, and clerical. Users in all seven job categories reported that using a MC enabled them to complete tasks more quickly, make fewer errors, increase quality and volume of output, and increase their overall productivity. The significant differences were attributed to the clerical category which had the greatest gains on each of the productivity measures. Also, users in all job categories were able to add new tasks and eliminate unneeded tasks.

User Microcomputer Satisfaction--Productivity and Task Loads

There was a significant relationship between user MC satisfaction and both productivity and task loads. Users who reported high MC satisfaction and those who reported low MC satisfaction both were able to complete tasks more quickly, make fewer errors, increase quality and volume of output, and increase their overall productivity than those who reported moderate MC satisfaction. Also, a larger percent of users at the high level of MC satisfaction were able to add new tasks or eliminate unneeded tasks than at the low level of MC satisfaction.

Access to Microcomputer--Productivity and Task Loads

Forty-nine percent of 637 users with a MC at their own work station also had access to alternate equipment away from their work station. Fifty-three percent of 533 respondents who did not have a MC at their own work station had access away and 47 percent had no access to a MC.

There were significant differences in the relationship between the access categories and both productivity and task loads. The greatest productivity gains in task loads, time, errors, quality of output, volume of output, and overall productivity were reported by users with both a MC at their own work station and access away. Users with only a MC at their own work station had the next largest gains. Users whose only MC access was away from their work station had the smallest gains.

Private or Shared Microcomputer--Productivity and Task Loads

Thirty-nine percent of 833 respondents had a private MC and 61 percent shared a MC. The extent of MC sharing at NAVTRASYSCEN was reported as follows: 191 users shared with one other user, 121 with two users, 75 with three users, 50 with four users, 26 with five users, and 44 with six or more coworkers. Further, 79 percent of 414 sharers said they would use a MC more if they had their own.

There was a significant relationship between sharing and both productivity and task loads. Private MC users reported that they were able to complete tasks more quickly, make fewer errors, increase quality and volume of output, and increase their overall productivity than reported by users who shared a MC. Also, a greater percent of users with a private MC were able to add new tasks and eliminate unneeded tasks than users who shared a MC.

Cost Analysis

The total discounted value of the improvement in quality and quantity of output from the use of MC's was estimated at $17.4 million. The toal discounted cost of acquisition, installation, training, and maintenance for the MC's over a six year life cycle was computed at $4.7 million. The difference of $12.7 million is the net discounted total value of benefits. This value divided by the total discounted value of output of $227.1 million yields an overall net productivity gain of 5.6 percent.

CONCLUSIONS

1. This study showed that an overwhelming majority of NAVTRASYSCEN employees perceived that their productivity had substantially increased since they began using a MC. Further, 97 percent of the fielded MC's were being utilized.

2. The cost analysis confirmed that the fielded MC's are highly cost-effective. Each dollar the Center has spent or will spend on the acquisition, installation, training, and maintenance of MC's over the life of the program will yield improvements in output valued at approximately $3.70 in present value terms.

3. The major software applications being used were word processing, electronic spreadsheets, and data management.

4. Nineteen percent of employees were potential new users of MC's; 10 percent of employees did not need a MC.

5. Nonsupervisors had greater productivity gains than supervisors.

6. Clericals increased their productivity more than workers in other job categories. The major software application for this group of users was word processing.

7. Users with a private MC had greater productivity gains than users who shared a MC. However, the greatest productivity gains were made by people with a private MC at their own work station who also had access to alternate equipment for special functions.

8. Highly satisfied users had greater productivity gains than moderately satisfied users.

RECOMMENDATIONS

The results of this study suggest that productivity could be further improved by:

1. Continuing to procure and allocate MC's to meet the functional needs of employees;

2. Procuring MC's for potential new users;

3. Allocating MC's to people who need and want them;

4. Allocating MC's to nonsupervisors before supervisors;

5. Allocating both MC's and the training slots in word processing to clericals before employees in other job categories;

6. Allocating MC's so that users have a private one at their own work station and access to alternate equipment for special functions.

7. Providing training in three priority software applications, word processing, electronic spreadsheets, and data base management;

8. Fostering a climate that increases acceptance and satisfaction with MC's by less satisfied users. The data suggests that satisfaction can be increased by eliminating MC sharing, by meeting functional needs, and by continuing to provide appropriate training and support.

TABLES AND FIGURES

The following pages of tables and figures are cited in the Results Section.

Table 1

Number and Percent of Sample by Department

Department	Number of Participants	Percent of Total Sample
0	114	8.7%
1	149	11.3%
2	277	21.0%
3	84	6.4%
4	412	31.3%
5	37	2.8%
6	132	10.0%
7	112	8.5%
Total	1317	100%

Table 2

Location of Zeniths Versus Other Microcomputers By Organizational Level

Organization Level	# Zenith Micros	# Other Micros	Total Micros	Percent Zeniths
Department	19	0	19	100%
Division	127	12	139	91%
Branch	515	85	600	86%
Total	661	97	758	87%

Table 3

Location of Zeniths Versus Other Microcomputers
By Department

Department	# Zenith Micros	# Other Micros	Total Micros	Percent Zeniths
0	48	4	52	92%
1	78	29	107	73%
2	166	11	177	94%
3	33	7	40	83%
4	245	21	266	92%
5	30	2	32	94%
6	23	4	27	85%
7	38	19	57	67%
Total	661	97	758	87%

Table 4

Microcomputers Used Versus Not in Use
By Organizational Level

Organization Level	Micros Used	Micros Not In Use	Total Micros	Percent Used
Department	19	0	19	100%
Division	139	0	139	100%
Branch	580	20	600	97%
Total	738	20	758	97%

Table 5

Microcomputers Used Versus Not In Use
By Department

Department	Micros Used	Micros Not In Use	Total Micros	Percent Used
0	51	1	52	98%
1	102	5	107	95%
2	172	5	177	97%
3	40	0	40	100%
4	261	5	266	98%
5	28	4	32	88%
6	27	0	27	100%
7	57	0	57	100%
Total	738	20	758	97%

Table 6

Number and Percent of Users Versus Nonusers
By Organizational Level

Organization Level	Users	Non Users	Total Employees	Percent Users
Department	18	10	28	64%
Division	162	108	270	60%
Branch	815	260	1075	76%
Total	995	378	1373	72%

Table 7

Number and Percent of Users Versus Nonusers
By Department

Department	Users	Non Users	Total Employees	Percent Users
0	70	48	118	59%
1	116	31	147	79%
2	259	28	287	90%
3	52	38	90	58%
4	377	74	451	84%
5	26	11	37	70%
6	35	92	127	28%
7	60	56	116	52%
Total	995	378	1373	72%

Table 8

Number and Percent in Each Department by Time Category

Department	Non User	1-3 Hours	4-10 Hours	11-20 Hours	21-30 Hours	30+ Hours	Total
			Number of Sample Reporting				
0	44	12	22	15	14	7	114
1	30	20	35	37	13	14	149
2	54	48	74	58	35	8	277
3	29	13	8	17	10	7	84
4	69	70	113	103	37	20	412
5	18	4	5	5	4	1	37
6	89	14	6	10	5	8	132
7	50	15	22	11	10	4	112
Total	383	196	285	256	128	69	1317
			Percent of Total Within Department				
0	39%	11%	19%	13%	12%	6%	100%
1	20%	13%	23%	25%	9%	9%	100%
2	19%	17%	27%	21%	13%	3%	100%
3	35%	15%	10%	20%	12%	8%	100%
4	17%	17%	27%	25%	9%	5%	100%
5	49%	11%	14%	14%	11%	3%	100%
6	67%	11%	5%	8%	4%	6%	100%
7	45%	13%	20%	10%	9%	4%	100%
Total	29%	15%	22%	19%	10%	5%	100%

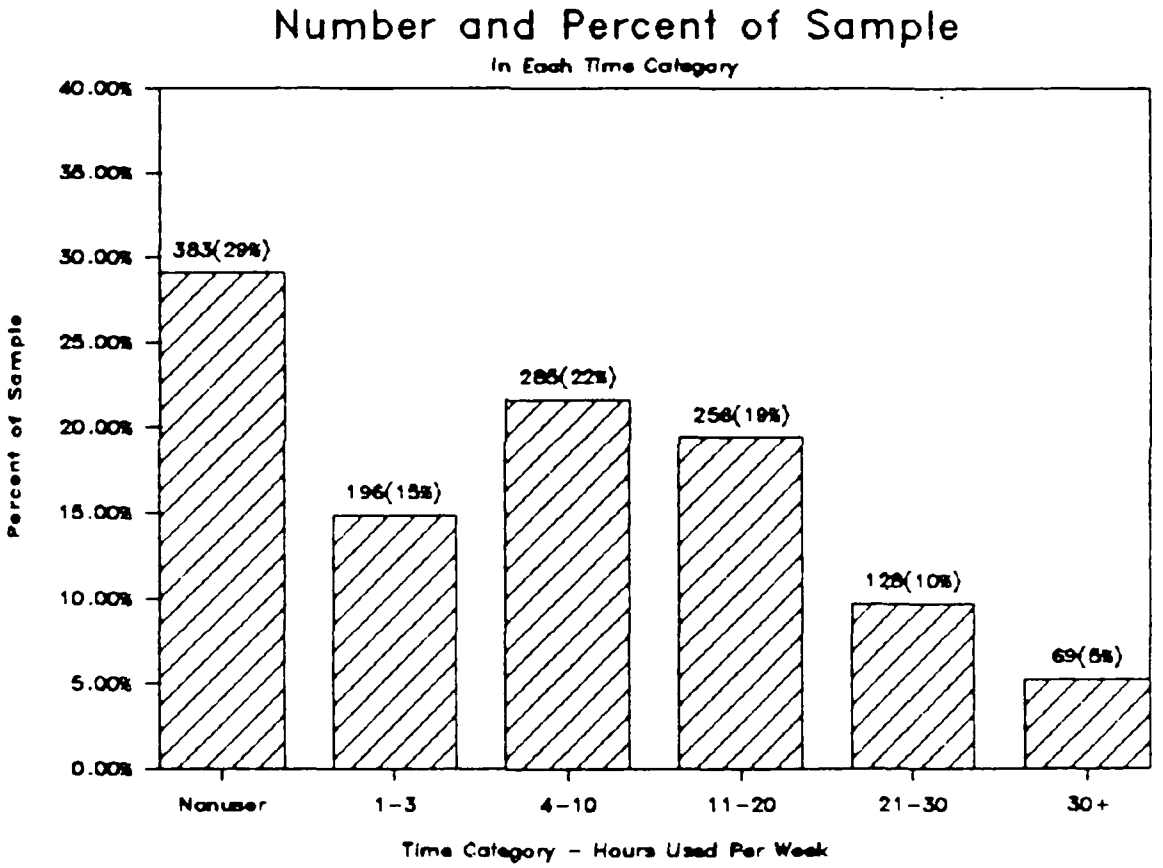

Figure 1. Number and percent of sample in each time category.

Table 9

Number and Percent in Each Time Category by Department

Department	Non User	1-3 Hours	4-10 Hours	11-20 Hours	21-30 Hours	30+ Hours	Total
			Number of Sample Reporting				
0	44	12	22	15	14	7	114
1	30	20	35	37	13	14	149
2	54	48	74	58	35	8	277
3	29	13	8	17	10	7	84
4	69	70	113	103	37	20	412
5	18	4	5	5	4	1	37
6	89	14	6	10	5	8	132
7	50	15	22	11	10	4	112
Total	383	196	285	256	128	69	1317
			Percent of Total Within Time Category				
0	11%	6%	8%	6%	11%	10%	
1	8%	10%	12%	14%	10%	20%	
2	14%	24%	26%	23%	27%	12%	
3	8%	7%	3%	7%	8%	10%	
4	18%	36%	40%	40%	29%	29%	
5	5%	2%	2%	2%	3%	1%	
6	23%	7%	2%	4%	4%	12%	
7	13%	8%	8%	4%	8%	6%	
Total	100%	100%	100%	100%	100%	100%	

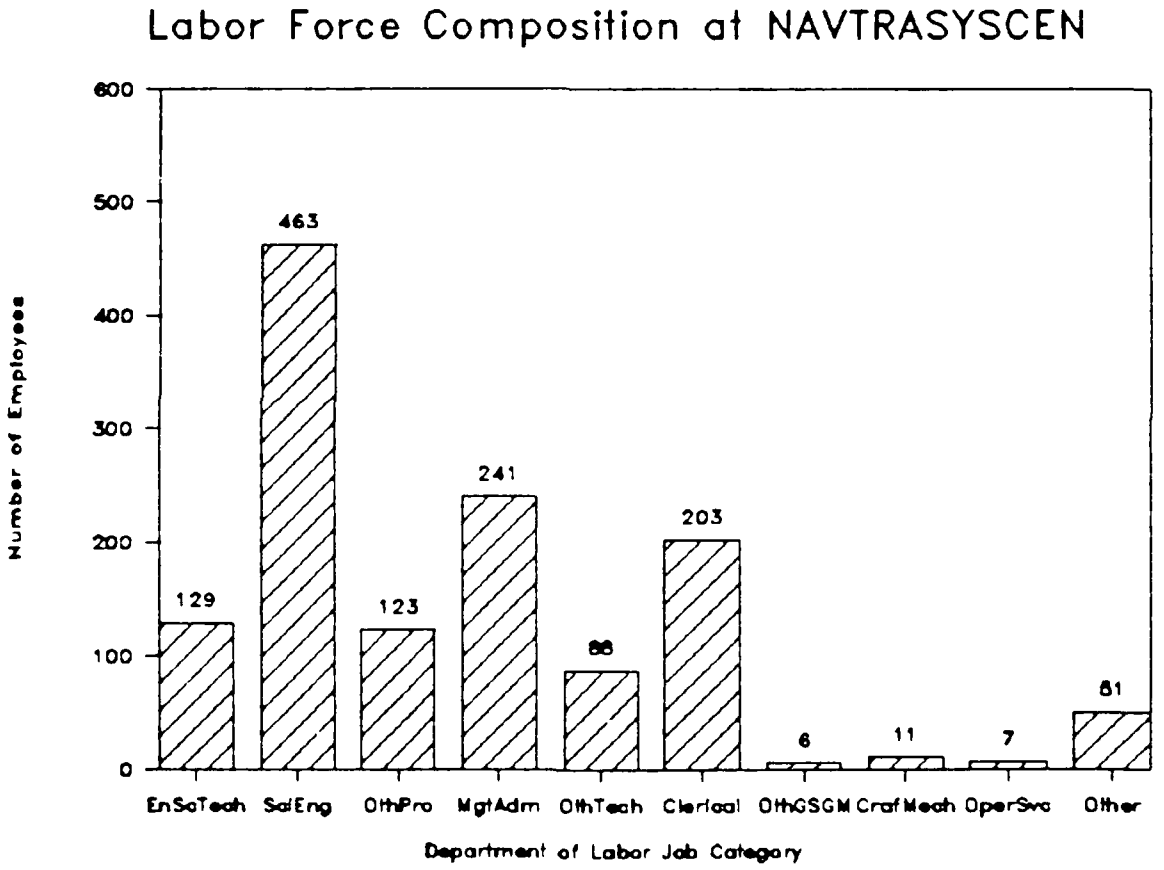

Figure 2. Labor force composition at NAVTRASYSCEN.

Table 10

Number and Percent of Sample in Each Job Category by Time Category

Labor Dept. Job Category	Non User	1-3 Hours	4-10 Hours	11-20 Hours	21-30 Hours	30+ Hours	Total
Number of Sample Reporting							
Engineer & Sci Tech	25	28	48	25	1	2	129
Scientist/Engineer	107	89	112	89	42	24	463
Other Professional	43	10	23	34	9	4	123
Management & Admin	107	33	37	40	15	9	241
Other Technician	24	15	29	13	5	2	88
Clerical	40	16	28	41	54	24	203
Other GS/GM	3	1	1	1	0	0	6
Craftsmen/Mechanic	11	0	0	0	0	0	11
Operatives/Service	4	0	2	1	0	0	7
Other	23	5	5	12	2	4	51
Total	387	197	285	256	128	69	1322
Percent of Total Within Job Category							
Engineer & Sci Tech	19%	22%	37%	19%	1%	2%	100%
Scientist/Engineer	23%	19%	24%	19%	9%	5%	100%
Other Professional	35%	8%	19%	28%	7%	3%	100%
Management & Admin	44%	14%	15%	17%	6%	4%	100%
Other Technician	27%	17%	33%	15%	6%	2%	100%
Clerical	20%	8%	14%	20%	27%	12%	100%
Other GS/GM	50%	17%	17%	17%	0%	0%	100%
Craftsmen/Mechanic	100%	0%	0%	0%	0%	0%	100%
Operatives/Service	57%	0%	29%	14%	0%	0%	100%
Other	45%	10%	10%	24%	4%	8%	100%
Total	29%	15%	22%	19%	10%	5%	100%

Table 11

Number and Percent of Sample in Each Time Category by Job Category

Labor Dept. Job Category	Non User	1-3 Hours	4-10 Hours	11-20 Hours	21-30 Hours	30+ Hours
			Number of Sample Reporting			
Engineer & Sci Tech	25	28	48	25	1	2
Scientist/Engineer	107	89	112	89	42	24
Other Professional	43	10	23	34	9	4
Management & Admin	107	33	37	40	15	9
Other Technician	24	15	29	13	5	2
Clerical	40	16	28	41	54	24
Other GS/GM	3	1	1	1	0	0
Craftsmen/Mechanic	11	0	0	0	0	0
Operatives/Service	4	0	2	1	0	0
Other	23	5	5	12	2	4
Total	387	197	285	256	128	69
			Percent of Total Within Time Category			
Engineer & Sci Tech	6%	14%	17%	10%	1%	3%
Scientist/Engineer	28%	45%	39%	35%	33%	35%
Other Professional	11%	5%	8%	13%	7%	6%
Management & Admin	28%	17%	13%	16%	12%	13%
Other Technician	6%	8%	10%	5%	4%	3%
Clerical	10%	8%	10%	16%	42%	35%
Other GS/GM	1%	1%	0%	0%	0%	0%
Craftsmen/Mechanic	3%	0%	0%	0%	0%	0%
Operatives/Service	1%	0%	1%	0%	0%	0%
Other	6%	3%	2%	5%	2%	6%
Total	100%	100%	100%	100%	100%	100%

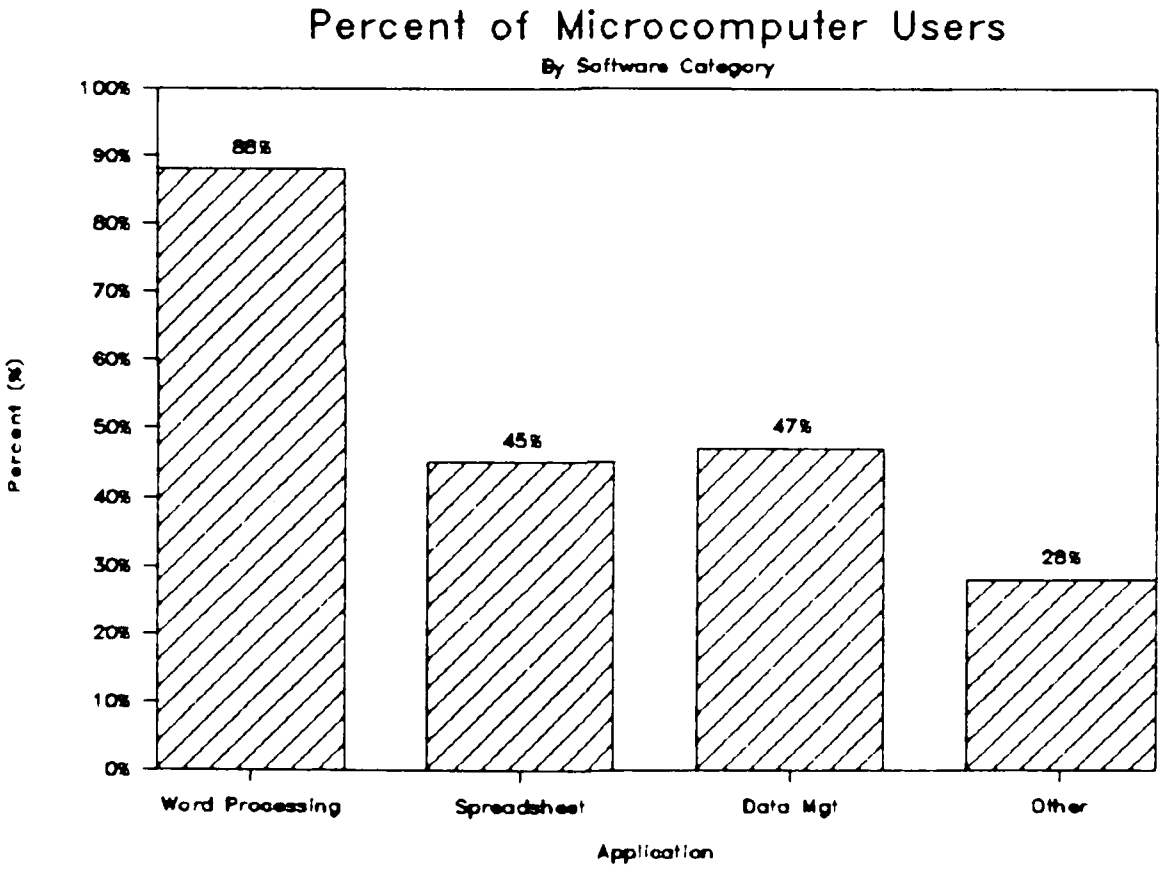

Figure 3. Percent of microcomputer users by software category.

Table 12

Number and Percent of Users in Each Department by Software Category

Department	Word Processing	Electronic Spreadsheet	Data Management	Other	Total Users*
		Number of Users Reporting			
0	56	22	31	9	70
1	105	49	60	37	119
2	205	121	102	80	223
3	56	33	28	11	56
4	287	146	174	86	343
5	11	8	5	2	19
6	43	24	14	6	43
7	56	20	21	33	62
Total	819	423	435	264	935
		Percent of Total Users Within Department			
0	80%	31%	44%	13%	100%
1	88%	41%	50%	31%	100%
2	92%	54%	46%	36%	100%
3	100%	59%	50%	20%	100%
4	84%	43%	51%	25%	100%
5	58%	42%	26%	11%	100%
6	100%	56%	33%	14%	100%
7	90%	32%	34%	53%	100%
Total	88%	45%	47%	28%	100%

* Total users is the total number of users in each department, not a horizontal summation of the numbers shown. These are multiple response data.

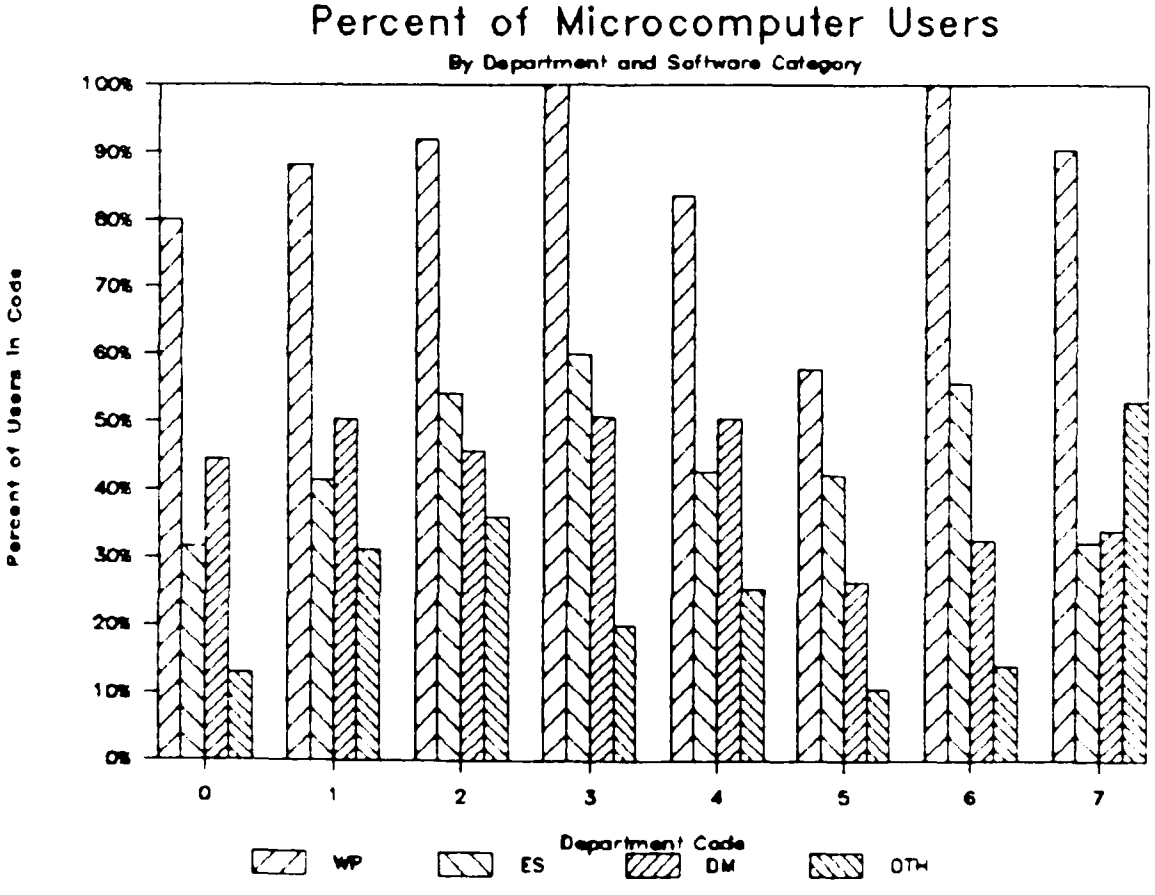

Figure 4. Percent of microcomputer users by department and software category.

Table 13

Number and Percent of Users in Each Software Category by Department

Department	Word Processing	Electronic Spreadsheet	Data Management	Other	Total Users*
		Number of Users Reporting			
0	56	22	31	9	70
1	105	49	60	37	119
2	205	121	102	80	223
3	56	33	28	11	56
4	287	146	174	86	343
5	11	8	5	2	19
6	43	24	14	6	43
7	56	20	21	33	62
Total	819	423	435	264	935
		Percent of Total Users Within Software Category			
0	7%	5%	7%	3%	7%
1	13%	12%	14%	14%	13%
2	25%	29%	23%	30%	24%
3	7%	8%	6%	4%	6%
4	35%	35%	40%	33%	37%
5	1%	2%	1%	1%	2%
6	5%	6%	3%	2%	5%
7	7%	5%	5%	13%	7%
Total	100%	100%	100%	100%	100%

* Total users is the total number of users in each department, not a horizontal summation of the numbers shown. These are multiple response data.

Table 14

Number and Percent of Users in Each Job Category by Software Category

Job Category	Word Processing	Electronic Spreadsheet	Data Management	Other	Total Users*
	Number of Users Reporting				
Engineer & Sci Tech	87	35	62	30	104
Scientist/Engineer	316	208	181	148	356
Other Professional	80	36	38	30	80
Management & Admin	122	75	53	25	134
Other Technician	38	24	35	13	64
Clerical	140	29	44	10	163
Other GS/GM	2	1	1	1	3
Craftsmen/Mechanic	0	0	0	0	0
Operatives/Service	3	1	2	1	3
Other	26	14	19	7	28
Total	814	423	435	265	935
	Percent of Total Users Within Job Category				
Engineer & Sci Tech	84%	34%	60%	29%	100%
Scientist/Engineer	89%	58%	51%	42%	100%
Other Professional	100%	45%	48%	38%	100%
Management & Admin	91%	56%	40%	19%	100%
Other Technician	59%	38%	55%	20%	100%
Clerical	86%	18%	27%	6%	100%
Other GS/GM	67%	33%	33%	33%	100%
Craftsmen/Mechanic	0%	0%	0%	0%	100%
Operatives/Service	100%	33%	67%	33%	100%
Other	93%	50%	68%	25%	100%
Total	87%	45%	47%	28%	100%

* Total users is the total number of users in each job category, not a horizontal summation of the numbers shown. These are multiple response data.

Table 15

Number and Percent of Users in Each Software Category by Job Category

Job Category	Word Processing	Electronic Spreadsheet	Data Management	Other	Total Users*
	Number of Users Reporting				
Engineer & Sci Tech	87	35	62	30	104
Scientist/Engineer	316	208	181	148	356
Other Professional	80	36	38	30	80
Management & Admin	122	75	53	25	134
Other Technician	38	24	35	13	64
Clerical	140	29	44	10	163
Other GS/GM	2	1	1	1	3
Craftsmen/Mechanic	0	0	0	0	0
Operatives/Service	3	1	2	1	3
Other	26	14	19	7	28
Total	814	423	435	265	935
	Percent of Total Users Within Software Category				
Engineer & Sci Tech	11%	8%	14%	11%	11%
Scientist/Engineer	39%	49%	42%	56%	38%
Other Professional	10%	9%	9%	11%	9%
Management & Admin	15%	18%	12%	9%	14%
Other Technician	5%	6%	8%	5%	7%
Clerical	17%	7%	10%	4%	17%
Other GS/GM	0%	0%	0%	0%	0%
Craftsmen/Mechanic	0%	0%	0%	0%	0%
Operatives/Service	0%	0%	0%	0%	0%
Other	3%	3%	4%	3%	3%
Total	100%	100%	100%	100%	100%

* Total users is the total number of users in each job category, not a horizontal summation of the numbers shown. These are multiple response data.

Table 16

Microcomputer Availability

Access Away	Own Workstation		Total
	No	Yes	
	Number of People Reporting		
No	253	328	581
Yes	280	309	589
Total	533	637	1170
	Percent of Total Number Reporting		
No	47%	51%	50%
Yes	53%	49%	50%
Total	100%	100%	100%

Table 17

Number of Users Sharing by Type of Access

Type of Access	One	Two	Three	Four	Five	Six	Total
	Number of Users Sharing						
Access Away Only	73	32	13	8	4	1	131
Own Work Station Only	56	61	50	36	18	37	258
Both	62	28	12	6	4	6	118
Total	191	121	75	50	26	44	507
	Percent of Total Users Sharing						
Access Away Only	38%	26%	17%	16%	15%	2%	26%
Own Work Station Only	29%	50%	67%	72%	69%	84%	51%
Both	32%	23%	16%	12%	15%	14%	23%
Total	100%	100%	100%	100%	100%	100%	100%

Table 18

Shared and Nonshared Usage by Type of Access

Type of Access	Private MC	Shared MC	Total
	Number of Users Reporting		
Access Away Only	2	258	260
Own Work Station Only	165	131	296
Both	159	118	277
Total	326	507	833
	Percent of Total Users Reporting		
Access Away Only	1%	51%	31%
Own Work Station Only	51%	26%	36%
Both	49%	23%	33%
Total	100%	100%	100%

Table 19

Percent of Users Reporting Changes in Productivity
By Productivity Measures

Effect on Productivity	Faster Time	Fewer Errors	Better Quality	Increased Volume	Overall Productivity
	Percent of Total Users Reporting				
Increased	79%	59%	73%	68%	74%
No Change	10%	18%	15%	18%	11%
Decreased	2%	7%	1%	1%	2%
Missing Cases	9%	15%	12%	12%	13%
Total No. Users	935	935	935	935	935
	Mean Percentage Change in Productivity				
Increased	18.7%	16.4%	20.0%	19.1%	17.6%
Decreased	6.5%	11.0%	5.8%	4.4%	5.6%

Table 20

Percent of Users Reporting Gains in Productivity
By Productivity Measures

Supervisory Status	Faster Time	Fewer Errors	Better Quality	Increased Volume	Overall Productivity
	Percent of Total Users Reporting				
Supervisor	11.2%	11.3%	11.7%	12.0%	12.6%
Nonsupervisor	88.8%	88.7%	88.3%	88.0%	87.4%
Total # Reporting	740	550	682	634	690
	Mean Gains in Productivity Measures*				
Supervisor	9.1%	10.8%	10.6%	9.4%	8.6%
Nonsupervisor	19.8%	17.1%	21.2%	20.4%	18.9%

* $P < .01$

Table 21

Percent of Users Reporting Gains in Productivity
By Job Category

Dept. of Labor Job Category	Faster Time	Fewer Errors	Better Quality	Increased Volume	Overall Productivity
	Percent of Users Reporting				
Engineer & Sci Tech	11.4%	13.0%	12.0%	11.8%	11.1%
Scientist/Engineer	38.0%	36.3%	37.5%	38.8%	40.2%
Other Professional	8.3%	7.7%	8.0%	8.3%	8.4%
Management & Admin	13.7%	14.5%	14.0%	13.8%	14.0%
Other Technician	6.4%	6.6%	6.9%	4.9%	5.5%
Clerical	18.8%	18.3%	17.9%	19.2%	17.8%
Other	3.4%	3.7%	3.7%	3.2%	3.1%
Total # Reporting	735	546	677	629	687
	Mean Gains in Productivity Measures*				
Engineer & Sci Tech	10.1%	9.8%	10.5%	10.7%	9.8%
Scientist/Engineer	15.7%	13.7%	16.2%	16.8%	14.0%
Other Professional	20.9%	18.0%	19.5%	19.0%	17.1%
Management & Admin	17.9%	16.1%	19.7%	16.5%	16.9%
Other Technician	17.0%	14.1%	17.5%	15.9%	14.0%
Clerical	29.2%	27.3%	34.5%	30.8%	31.4%
Other	23.2%	16.0%	26.7%	24.2%	20.4%

* $P < .01$

Table 22

Percent of Users Reporting Gains in Productivity
By Level of Satisfaction

Level of MC Satisfaction	Faster Time	Fewer Errors	Better Quality	Increased Volume	Overall Productivity
			Percent of Users Reporting		
Low	8.3%	9.4%	9.3%	8.5%	9.1%
Moderate	36.3%	36.8%	37.8%	35.1%	35.9%
High	55.4%	53.8%	53.0%	56.4%	55.0%
Total # Reporting	725	541	670	626	660
			Mean Gains in Productivity Measures*		
Low	17.3%	14.2%	20.2%	17.3%	16.9%
Moderate	13.1%	12.5%	14.9%	14.0%	12.4%
High	22.6%	19.4%	23.8%	22.7%	21.4%

* $P < .01$

Table 23

Percent of Users Reporting Gains in Productivity
By Access Category

Access Category	Faster Time	Fewer Errors	Better Quality	Increased Volume	Overall Productivity
	Percent of Users Reporting				
Both	36.3%	36.7%	35.4%	36.6%	36.2%
Own Workstation	35.3%	33.6%	36.0%	35.0%	34.8%
Access Away	28.5%	29.7%	28.7%	28.0%	29.0%
Total # Reporting	731	542	673	625	683
	Mean Gains in Productivity Measures*				
Both	25.8%	21.3%	27.4%	26.5%	24.2%
Own Workstation	18.9%	18.1%	19.8%	18.3%	18.0%
Access Away	9.5%	8.7%	11.4%	10.8%	9.1%

* $P < .01$

Table 24

Percent of Users Reporting Gains in Productivity
By Share Category

Share Category	Faster Time	Fewer Errors	Better Quality	Increased Volume	Overall Productivity
	Percent of Users Reporting				
Private MC	40.1%	38.1%	39.2%	41.2%	41.4%
Shared MC	59.9%	61.9%	60.8%	58.8%	58.6%
Total # Reporting	678	507	625	575	631
	Mean Gains in Productivity Measures*				
Private MC	23.8%	21.9%	25.5%	23.0%	22.1%
Shared MC	15.1%	13.3%	16.5%	15.9%	14.2%

* $P < .01$

Table 25

Number and Percent of Users Reporting a Change In Task Load

Response	Eliminate Tasks	Take On New Tasks
Number of Users Reporting		
Yes	401	574
No	428	296
Total # Reporting	829	870
Percent of Total Number Reporting		
Yes	48%	66%
No	52%	34%

Table 26

Number and Percent of Users Reporting a Change in Task Load
By Supervisory Status

Supervisory Status	Took on New Tasks		Total	Eliminated Tasks		Total
	Yes	No		Yes	No	
	Number of Users Reporting					
Supervisor	70	29	99	47	47	94
Nonsupervisor	504	267	771	354	381	735
Total # Reporting	574	296	870	401	428	829
	Percent of Users Reporting Within Supervisory Status					
Supervisor	71%	29%	100%	50%	50%	100%
Nonsupervisor	65%	35%	100%	48%	52%	100%

Table 27

Number and Percent of Users Reporting a Change in Task Load
By Job Category

Dept. of Labor Job Category	Took on New Tasks		Eliminated Tasks	
	Yes	No	Yes	No
Engineer & Sci Tech	69	28	49	46
Scientist/Engineer	208	126	142	181
Other Professional	48	28	34	37
Management & Admin	77	46	55	64
Other Technician	47	14	25	28
Clerical	102	45	79	59
Other	19	7	14	11
Total # Reporting	570	294	398	426

Table 28

Number and Percent of Users Reporting a Change in Task Load
By Time Category*

Time Category	Took on New Tasks			Eliminated Tasks		
	Yes	No	Total	Yes	No	Total
1-3 Hours	78	97	175	58	111	169
4-10 Hours	178	87	265	116	128	244
11-20 Hours	170	77	247	131	108	239
21-30 Hours	94	24	118	58	56	114
More than 30 Hours	54	11	65	38	25	63
No. Users Reporting	574	296	870	401	428	829

* $P < .01$

Table 29

Number and Percent of Users Reporting a Change in Task Load
By Satisfaction Level*

Satisfaction	Took on New Tasks		Total	Eliminated Tasks		Total
	Yes	No		Yes	No	
	Number of Users Reporting					
Low	37	44	81	30	45	75
Moderate	192	137	329	134	181	315
High	339	107	446	234	191	425
Total # Reporting	568	288	856	398	417	815
	Percent of Users Reporting Within Satisfaction Level					
Low	46%	54%	100%	40%	60%	100%
Moderate	58%	42%	100%	43%	57%	100%
High	76%	24%	100%	55%	45%	100%

* $P < .01$

Table 30

Number and Percent of Users Reporting a Change in Task Load By Access Category*

Access Category	Took on New Tasks		Total	Eliminated Tasks		Total
	Yes	No		Yes	No	
Number of Users Reporting						
Both	219	81	300	159	129	288
Own Workstation	195	104	299	132	151	283
Access Away	154	105	259	107	140	247
Total # Reporting	568	290	858	398	420	818
Percent of Users Reporting Within Access Category						
Both	73%	27%	100%	55%	45%	100%
Own Workstation	65%	35%	100%	47%	53%	100%
Access Away	59%	41%	100%	43%	57%	100%

* $P < .01$

Table 31

Number and Percent of Users Reporting a Change in Task Load By Share Category*

Share Category	Took on New Tasks			Eliminated Tasks		
	Yes	No	Total	Yes	No	Total
	Number of Users Reporting					
Private MC	214	88	302	150	141	291
Shared MC	303	184	487	217	243	460
Total # Reporting	517	272	789	367	384	751
	Percent of Users Reporting Within Share Category					
Private MC	71%	29%	100%	52%	48%	100%
Shared MC	62%	38%	100%	47%	53%	100%

* P < .01 for Took on New Task data only, Eliminated Tasks data was insignificant.

Table 32

Life Cycle Valuation of Output and Productivity

		FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	Total
Estimated Value of Output*	(1)	$39,001,920	$40,627,000	$40,627,000	$41,845,810	$43,310,413	$44,826,278	$250,238,421
Estimated Value of increase in Productivity**	(2)	$2,277,760	$2,827,673	$3,209,000	$3,510,351	$3,763,453	$3,983,741	$19,571,979
Discounted Value of Output	(3)	$43,097,122	$42,658,350	$38,758,158	$36,280,317	$34,128,606	$32,140,441	$227,062,994
Discounted Value of increase in Productivity	(4)	$2,516,924	$2,969,057	$3,061,386	$3,043,475	$2,965,601	$2,856,342	$17,412,786
Percent Gain (4)/(3)***	(5)	5.84%	6.96%	7.90%	8.39%	8.69%	8.89%	7.67%

* Value of output is assumed to be equal to employee wages. Wages were estimated using the employees pay grades and the General Schedule for civilian pay at the step 6 level. The salary estimates are accurate within plus or minus eight percent.

** An 80.5 percent learning curve was applied to the FY 1986 increase in productivity to derive the other values.

*** Percent gains excluding costs.

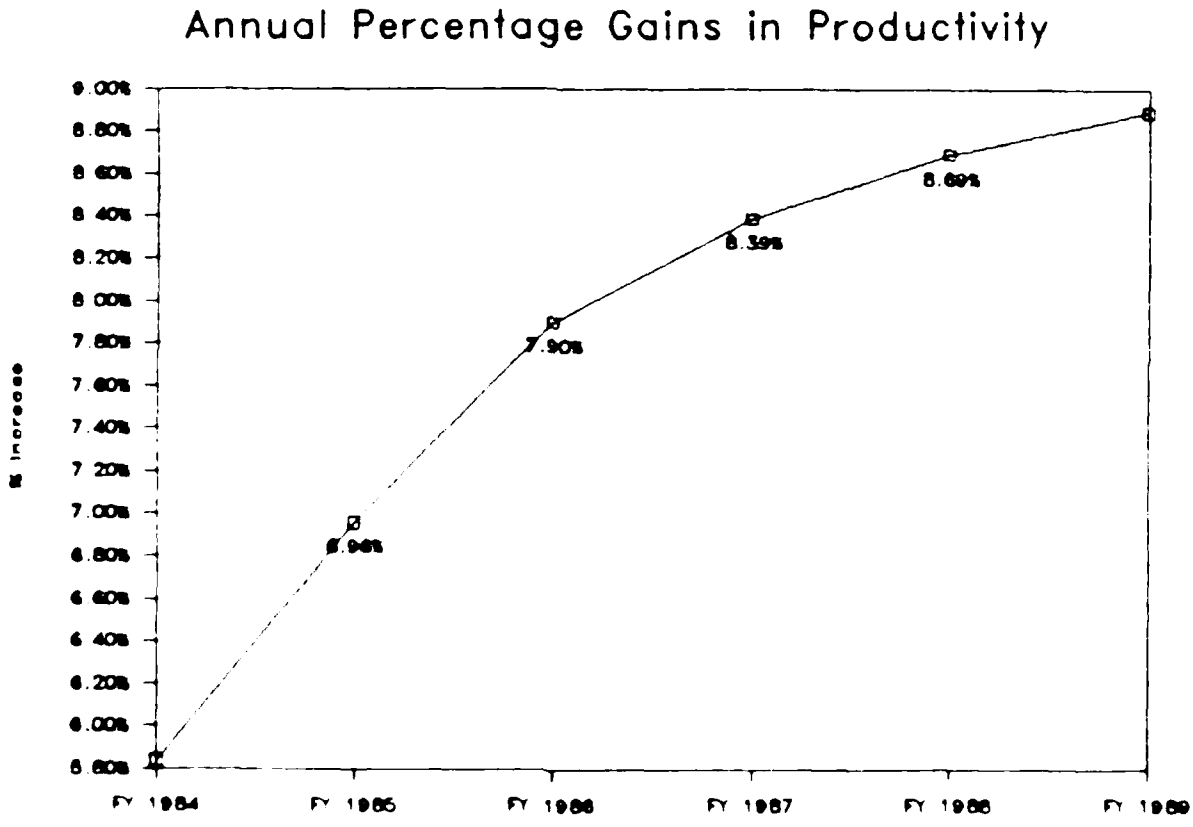

Figure 1. Annual percentage gains in productivity.

Table 33

Life Cycle Cost Analysis
Costs (+) and Savings (-)

Cost Category	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	Total
INVESTMENT:							
Hardware and Software (H&S)	$1,056,662	$1,113,811	$1,050,000	$600,000	$50,000	$50,000	$3,920,573
Typewriters & Word Processors (T&WP)	($32,400)	($32,400)	($32,400)	($32,400)	($32,400)	($32,400)	($194,400)
OPERATING AND SUPPORT:							
Maintenance (H&S)	$10,000	$20,000	$35,000	$100,000	$100,000	$100,000	$365,000
Maintenance (T&WP)	($12,090)	($12,090)	($12,090)	($12,090)	($12,090)	($12,090)	($72,540)
Training (H&S)	$0	$80,000	$126,558	$110,000	$110,000	$110,000	$536,558
Supplies (H&S)	$16,500	$34,000	$47,500	$57,500	$57,500	$57,500	$270,500
Supplies (T&WP)	($10,750)	($10,750)	($10,750)	($10,750)	($10,750)	($10,750)	($64,500)
Electricity (H&S)	$4,531	$9,336	$13,044	$15,790	$15,790	$15,790	$74,279
Electricity (T&WP)	($2,954)	($2,954)	($2,954)	($2,954)	($2,954)	($2,954)	($17,722)
Total *	$1,029,499	$1,199,054	$1,213,908	$825,096	$275,096	$275,096	$4,817,748
Discounted Total *	$1,137,597	$1,259,006	$1,158,068	$715,358	$216,775	$197,244	$4,684,046

* This analysis examines the costs of the microcomputers using mid-1986 as the base. As a result, pre-1986 dollars must be adjusted upward to reflect costs in mid-1986 terms.

Table 34

Cost-Benefit Analysis

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	Total
Discounted Value of Benefits	$2,516,924	$2,969,057	$3,061,386	$3,043,475	$2,965,601	$2,856,342	$17,412,786
Discounted Cost	$1,137,597	$1,259,006	$1,158,068	$715,358	$216,775	$197,244	$4,684,048
Net Discounted Value of Total Benefits	$1,379,328	$1,710,051	$1,903,318	$2,328,117	$2,748,826	$2,659,098	$12,728,737

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APPENDIX A

MICROCOMPUTER STUDY

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MICRO COMPUTER STUDY - QUESTIONNAIRE FOR SUPERVISORS

DIRECTIONS: Answer ALL QUESTIONS using one of these Responses.
A CHECK MARK; A NUMBER; A FEW WORDS; OR N.A. (Does Not Apply)

(Check)

NAME _____ DEPT. HEAD _____
JOB SERIES _____ CODE _____ DIV. HEAD _____
JOB TITLE _____ BRANCH HEAD _____

YOUR THOUGHTFUL PARTICIPATION IS VERY MUCH APPRECIATED. THANK YOU.

AUTOVON TEL. _____ COMMERCIAL TEL. (_____) _____

PERSONAL COMPUTER(PC) DATA - PUT A NUMBER IN THE SPACE BELOW

1 _____ How many PCs being used in your Unit? How many Zeniths? _____
2 _____ How many PCs NOT being used?
3 _____ Total # PCs in your unit?

REASONS FOR NON USE--CHECK ALL THAT APPLY

1 _____ PC malfunction
2 _____ Peripheral malfunction (printer/modem/etc.)
3 _____ Need peripheral (printer/modem/etc.)
4 _____ Need training
5 _____ Need software
6 _____ Use other equipment or methods
7 _____ Employee resistance
9 _____ Other (Explain) _____

WHAT WOULD YOU NEED TO GET MAXIMUM USE OF PC SYSTEMS?
(Check all that apply)

1 ____ Peripherals (Modems/Printers, Etc.)
2 ____ Maintenance support for PC and/or peripherals
3 ____ Software: What Kind? _____
4 ____ Training: What Kind? _____
5 ____ On-Job-Training / Hotline follow up to training
6 ____ PCs at every desk (Not linked to each other)
7 ____ PC Network (Workers talk to each other by computer)
8 ____ Electronic Mail (Send documents by computer)
9 ____ Automated Information System (Access to corporate/other Large Data Bases
10 ____ Other (Explain) _____

CONTINUE ON REVERSE SIDE

3-3-86

EMPLOYEE INFORMATION - PUT A NUMBER IN THE SPACE BELOW

HOW MANY OF YOUR PEOPLE:

1 _____ Use a Personal Computer at their own workstation?
2 _____ Use a shared PC away from own workstation?
3 _____ DO NOT use a PC?
4 _____ TOTAL number of Employees

5 HOW MANY WHO SHARE NEED THEIR OWN PC? _____
6 HOW MANY NON USERS NEED THEIR OWN PC? _____

ESTIMATE THE EFFECT OF PCs ON PRODUCTIVITY AND/OR OUTPUT OF YOUR UNIT.
(Put a Percent in the appropriate column.)

		PERCENT % Increase	No Effect	PERCENT % Decrease
1	TIME	FASTER_____%	_____	_____% SLOWER
2	ERRORS	MORE _____%	_____	_____% LESS
3	QUALITY	BETTER_____%	_____	_____% WORSE
4	VOLUME OF OUTPUT	MORE _____%	_____	_____% LESS
5	OVERALL PRODUCTIVITY	MORE _____%	_____	_____% LESS

HAVE PCs ALLOWED YOUR PEOPLE TO: (Check)

TAKE ON NEW TASKS NEVER DONE BEFORE? YES _____ NO_____
ELIMINATE FORMER TASKS NOT NOW NEEDED? YES _____ NO_____

SATISFACTION WITH PERSONAL COMPUTERS
(Check/List PCs in your Unit) AND RATE YOUR SATISFACTION

		Low				High
1____	ZENITH- - - - - - - - - -	1	2	3	4	5
2____	APPLE - - - - - - - - - -	1	2	3	4	5
3____	IBM - - - - - - - - - -	1	2	3	4	5
	(List)					
4	IBM Compatible (Kind?) _____	1	2	3	4	5
5	Other Kind?_____	1	2	3	4	5
6	Other Kind?_____	1	2	3	4	5
7	Other Kind?_____	1	2	3	4	5

SATISFACTION WITH SOFTWARE
(Check/List SOFTWARE in your Unit) AND RATE YOUR SATISFACTION

		Low				High
1____	PEACHTEXT WP - - - - - - -	1	2	3	4	5
2____	WORDSTAR WP - - - - - - -	1	2	3	4	5
3____	MULTIMATE WP - - - - - - -	1	2	3	4	5
4____	dBASE - - - - - - - -	1	2	3	4	5
5____	CONDOR - - - - - - - -	1	2	3	4	5
6____	LOTUS 1 2 3 - - - - - - -	1	2	3	4	5
7____	GRAPHTALK- - - - - - - -	1	2	3	4	5
	(List)					
8	Other Kind?_____	1	2	3	4	5
9	Other Kind?_____	1	2	3	4	5

GENERAL COMMENTS:_____
_____

Return to B. Best NTSC, Code 123, Orlando, FL.

MICRO COMPUTER STUDY - QUESTIONNAIRE FOR INDIVIDUALS
(Including Supervisors)

DIRECTIONS: ANSWER ALL QUESTIONS using one of these Responses.
a Check mark; a Number; a Few Words; OR N.A. (Does Not Apply)

NAME _____
JOB SERIES_____ CODE_____
JOB TITLE_____

RETURN TO:
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YOUR THOUGHTFUL PARTICIPATION IS VERY MUCH APPRECIATED. THANK YOU.

AUTOVON TEL._____-_____ COMMERCIAL TEL. (___)_____-_____

PERSONAL COMPUTER (PC) INFORMATION:

YES NO CHECK THE APPROPRIATE BOX AND FILL IN THE BLANK

___ ___ Do you have a PC at own workstation? What kind?_____
___ ___ Do you have access to a PC away from station? Kind?_____
___ ___ Would you use a PC more if you had your own?

How many share the PC you use (including yourself)?_____

SATISFACTION with the PC you use -- Low (Circle) High 1 2 3 4 5 6 I would prefer a _____

CHECK THE BOX BELOW THAT COMES CLOSEST TO THE AVERAGE NUMBER OF HOURS PER WEEK YOU USE A PERSONAL COMPUTER

/_____/_____/_____/_____/_____/_____/
NON USER 1-3 hrs 4-10 hrs 11-20 hrs 21-30 HRS OVER 30 HRS

REASONS for NON USE and/or UNDER USE(IF APPLICABLE):

CHECK ALL THAT APPLY
1 ____ Not required by my job
2 ____ Not needed - use other equipment or methods
3 ____ No machine available
4 ____ Shared machine available but inconvenient
5 ____ PC malfunction
6 DOWNTIME_____How many days during past 2 weeks?
7 ____ Peripheral malfunction (printer/modem/etc.)
8 DOWNTIME_____How many days during past 2 weeks?
9 ____ Need training: What kind _____
10____ Need software: What kind _____
11____ Need peripherals (printer/modem etc.)
12____ Other: Explain _____

CONTINUE ON REVERSE SIDE

3-3-86

USERS: On Chart below RANK ORDER FUNCTIONS you use the PC for.
PUT "1" beside the function you do the most.
PUT "2" beside the next most used function; then "3" ETC.
PUT "N.A." beside the functions you do not use.

ALSO: LIST SOFTWARE PACKAGES AND RATE YOUR SATISFACTION

RANK NUMBER		LIST SOFTWARE USED (One per line)	SATISFACTION (Circle) Low 1 2 3 4 5 High	I WOULD PREFER
1____	WORDPROCESSING	_____	1 2 3 4 5	_____
2____	Other WP	_____	1 2 3 4 5	_____
3____	SPREADSHEET	_____	1 2 3 4 5	_____
4____	PROGRAMMING	_____	1 2 3 4 5	_____
5____	DATA ENTRY	_____	1 2 3 4 5	_____
6____	DATA MANAGEMENT	_____	1 2 3 4 5	_____
7____	DESIGN/ANALYSIS	_____	1 2 3 4 5	_____
8____	MODELING/TESTING	_____	1 2 3 4 5	_____
9____	OTHER?_____	_____	1 2 3 4 5	_____
10____	OTHER?_____	_____	1 2 3 4 5	_____
11____	OTHER?_____	_____	1 2 3 4 5	_____

ON CHART BELOW:

USERS: Estimate PERCENT effect on your output of USING a PC.
NON USERS: Estimate PERCENT effect on your output IF YOU HAD A PC

PRODUCTIVITY	PERCENT % Increase	No Effect	PERCENT % Decrease
1 TIME	FASTER_____%	____	_____% SLOWER
2 ERRORS	MORE _____%	____	_____% LESS
3 QUALITY OF OUTPUT	BETTER_____%	____	_____% WORSE
4 VOLUME OF OUTPUT	MORE_____%	____	_____% LESS
5 OVERALL PRODUCTIVITY	MORE_____%	____	_____% LESS

1 _____What PERCENT of your time do you use a PERSONAL COMPUTER?
2 _____What PERCENT of your time do you use a TYPEWRITER?

HAVE PCs ALLOWED YOU TO: (Check)

TAKE ON NEW TASKS NEVER DONE BEFORE? YES_____ NO_____
ELIMINATE FORMER TASKS NOT NOW NEEDED? YES_____ NO_____

WHAT WOULD YOU NEED TO GET MAXIMUM USE OF PC SYSTEMS?
(Check all that apply)

1 _____ A PC AT YOUR OWN STATION
2 _____ PERIPHERALS (MODEM/PRINTER, ETC.)_____
3 _____ TRAINING: What Kind?_____
4 _____ SOFTWARE: What Kind?_____
5 _____ ON-JOB-TRAINING and/or HOTLINE FOLLOW UP TO TRAINING
6 _____ MAINTENANCE SUPPORT
7 _____ PCs NETWORK (Workers talk to each other by commputer)
8 _____ ELECTRONIC MAIL (Send documents by computer)
9 _____ AUTOMATED INFORMATION SYSTEM (Access to Corporate/Other Large Data Bases)
10____ OTHER (Explain) _____

GENERAL COMMENTS:_____

Table 25

Statistical Measures of Significance for Tables With Productivity Measures

	Faster Time	Fewer Errors	Better Quality	Increased Volume	Overall Productivity
Table 20					
Variance Explained	0.025	0.010	0.020	0.026	0.030
Eta	0.156	0.107	0.153	0.161	0.175
F	19.000	6.400	16.400	16.900	21.800
P	.000	0.020	.000	.000	.000
Table 21					
Variance Explained	0.070	0.090	0.110	0.080	0.120
Eta	0.272	0.299	0.337	0.281	0.352
F	9.660	8.810	14.310	8.900	16.070
P	.000	.000	.000	.000	.000
Table 22					
Variance Explained	0.040	0.030	0.030	0.030	0.040
Eta	0.208	0.178	0.188	0.183	0.214
F	16.300	8.840	12.220	10.780	16.300
P	.000	.000	.000	.000	.000
Table 23					
Variance Explained	0.090	0.080	0.080	0.080	0.100
Eta	0.303	0.282	0.285	0.283	0.309
F	36.720	23.260	29.720	27.110	35.800
P	.000	.000	.000	.000	.000
Table 24					
Variance Explained	0.040	0.050	0.040	0.025	0.040
Eta	0.197	0.228	0.197	0.158	0.197
F	27.190	27.690	25.100	14.670	25.910
P	.000	.000	.000	.000	.000

Table 36

Statistical Measures of Significance for Tables With Task Loads

	Took on New Tasks	Eliminated Tasks
Table 28		
Variance Explained	0.060	0.020
Eta	0.250	0.160
Chi-Square	55.090	21.290
P	.000	.000
Table 29		
Variance Explained	0.050	0.020
Eta	0.226	0.131
F	43.550	13.930
P	.000	0.001
Table 30		
Variance Explained	0.010	0.010
Eta	0.116	0.100
F	11.580	8.220
P	0.003	0.016
Table 31		
Variance Explained	0.010	NS*
Eta	0.088	NS
F	6.170	NS
P	0.013	NS

* Not significant

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